Toward Sustainable Households: Passive Context-Aware Intervention to Promote Reduction in Food Waste

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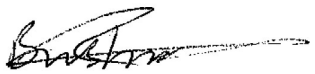
Signed 

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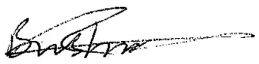
Signed 

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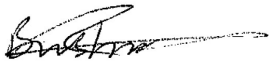
Signed 

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Abstract

Food waste, a global concern for several years, has gained attention from Human-Computer Interaction (HCI) research that aims to promote more sustainable lifestyles. Many researchers believe that domestic food waste is influenced by consumer behaviors that are promoted during everyday practices. The research described in this thesis starts with an investigation into the factors that influence consumer decision-making in ways that leads to food waste. The investigation was conducted using a combination of structured interviews, automatic collection of images from participants' fridges, and Wizard-of-Oz interventions. The four causal variables of VBN theory are used throughout the thesis to structure and analyze data. These four variables are attitudinal factors, personal capabilities, contextual forces and habits or routines. The most significant of these factors, leading to the greatest amount of domestic food waste, is lack of awareness of fridge contents. This is addressed by building an effective context-aware persuasive technology. In an initial experiment, the design and implementation of a first prototype is proposed to investigate the impact of the context-aware persuasive technology system on behavior change and decision-making process. The findings indicated that availability of information about fridge contents was not in itself sufficient to persuade users to develop new habits or routines, and that contextual forces such as a busy lifestyle meant that users did not in fact enhance their personal capabilities by accessing the information about fridge contents, and that their old habits remained entrenched. These findings informed the design of an improved second prototype, called 'EyeFridge'. This prototype has the novel functionality of pushing information over to users through notifications and reminders. A Wizard-of-Oz investigation allowed the effectiveness of these interventions to be studied without the need to build a fully functional intelligent fridge. The findings indicate that notifications and reminders overcame contextual forces and enhanced participants' personal capabilities (by adding to their knowledge of fridge contents) so that they developed new habits or routines. Therefore, changed consumer behavior and influenced decision-making process related to food practices.

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As for my mother, who always encouraged me to achieve my goals, this dissertation is for you. Thanks also to my sisters Huda, Ebtesam, Mona, Hanan, Abeer, Fadwa, and my oldest nephew, Ahmed, who encouraged me with their love and support. My gratitude also goes to my colleagues and fellow PhD students for their encouragement, and particularly, Peter Scully, for his advice and feedback. Lastly, thanks to my dear friends Hatice, and Sarah for their support.

Dedication

To the memory of my dad.

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Chapter 1 Introduction

This chapter presents the background to the research and describes research objectives as well as questions identified. This chapter also provides the research statement and contributions. In addition, it outlines the structure of each chapter of the thesis.

1.1 Research Background

Ecological sustainability is becoming a global problem that has gained attention in the area of Human-Computer Interaction (HCI) to support more sustainable practices. Another area for growing concern in sustainability is food. The way we consume and produce food has an impact on population (Choi and Blevis, 2010; Cuellar and Webber, 2010), which affects our greenhouse gas emissions and environmental aspects such as climate and flora (Change, 2007). This presents an opportunity to study future technology to either encourage or discourage individuals to change their behaviours to reduce food waste. For example, food waste affects the economy, environment, energy consumption, transportation choices, food security, and land availability (Gustavsson et al., 2011; Halloran et al., 2014; Quested et al., 2013; Froehlich et al., 2009; Fitzpatrick and Smith, 2009).

Sustainability in the food domain can be divided into three main areas. The first, an animal-based diet, generates further greenhouse gas emissions (Eshel and Martin, 2006). The second, organic farming and organic food consumption (Pimental et al., 2005), does not involve less resource-intensive farming methods (Weber and Matthews, 2008). The last area, food waste environmental impact (Hall et al., 2009), is the key motivation in this thesis.

The majority of food waste is generated from households in developed countries (Parfitt et al., 2010). A study in the USA has shown that 27% of consumed food is wasted—that is equal to 2% of the annual energy consumption (Cuellar and Webber, 2010). In the UK,

approximately 30% of food waste is generated from households (Amber-Edwards et al., 2009). Consumers in the UK are still wasting 4.2 million tonnes of food and drink annually, which is equal to six meals every week (Wrap, 2014). Food waste through overbuying and food spoil generates greenhouse gas emissions that might be simply avoided if we produce and consume the food needed. Thus the potential for interventions to make a difference is significant. Other factors such as food price for every household (Wrap, 2011) and users wanting to spend less money on food give rise to opportunities for interventions.

Reducing domestic food waste could have a significant positive environmental effect. For instance, if an average UK household reduced their food and drink waste, this has the potential to reduce greenhouse gas emissions. It would be equal to installing 270 mm of loft insulation or booking an annual return flight from the UK to Europe for all household members (Wrap, 2014).

These findings shows how behaviour change could potentially affect resource consumption and suggest that intervention strategies to promote sustainable behaviours could result in significant reduction of food waste. A key problem is that most people are unaware of how their daily activities affect the environment, and they have few resources to find out. The main focus in this issue is consumer decision-making process when it comes to food planning and shopping, and how these practices could influence food waste.

Therefore, this thesis focuses on the role of data from the home environment in reducing food waste. The following important considerations should be included:

- Deciding what data to collect
- Determining how to collect data
- Transforming data to meaningful information
- Using data to recall previous interactions with food in the home thus change behaviour
- Increasing reflection on, and awareness of, food waste
- Ensuring on-going, long-term engagement of people with data about food in the home

Lately, significant research has been carried out in HCI into the potential of technology to change consumers' beliefs, to form their attitudes, and to change their behavior (Fogg et al., 2002). Persuasive technology has been used in previous research to build technologies that have an impact on ecological sustainability (Rouillard, 2012; Bucci et al., 2010; Thieme et al., 2012; Farr-Wharton et al., 2012; Lim et al., 2014), healthcare (Matthews & Doherty, 2011) education (Fogg et al., 2002), and greener transportation habits (Frohlich et al, 2009).

In this thesis, the focus is to understand everyday food practices to identify factors influence consumer's behaviour resulting in food waste using the value-belief-norm (VBN) theory lens (Stern, 2000). This theory and reasons chosen for this thesis explained later in section (2.2.1). Identifying these factors will raise opportunities for persuasive and context-aware technologies to support long-term behaviour change and decision-making process in domestic settings.

Although this thesis addresses environmental issues related to food waste, the present work does not focus only on sustainability research but uses it as a domain area to investigate approaches borrowed from social psychology to promote behaviour change with focus on awareness, reflection, engagement, and consumer decision-making process through digital design (Cialdini and Goldstein, 2004). The results in this thesis should benefit researchers working in sustainability, including researchers from HCI/Ubicomp, environmental, social psychology, and field workers.

1.2 Thesis Statement

This thesis investigates the impact of context-aware persuasive technology on consumer's decision-making process and long-term behaviour change in everyday food practices. The proposed technology is investigated through two case studies using real-life participants to understand the research problem, fill in literature gaps and the extent to which the technology is successful in providing desired support. In addition, addresses the problem of food waste, its causes, and the impact of persuasive technology in consumer's everyday lives. Such

technologies should assist consumers in capturing, storing, and presenting collected data from home environment. Furthermore, study context data that is collected from sensors needs to be investigated and assessed to see how consumers could employ such information during decision-making process when it comes to food practices and also promote ecological sustainability in terms of food waste reduction.

1.3 Research Objectives

- Critically review the literature in relation to domestic food waste, behavioural science, sustainable HCI, context-aware, persuasive technology, behaviour change and habits, and current interventions to reduce food waste.
- Study the causes leading to domestic food waste under the scope of VBN theory and how these causes could be used as a starting point to help build effective persuasive context–aware technology.
- Design and build persuasive context-aware technology that can be mastered easily and assist consumers accessing captured data to support decision-making process.
- Introduce new methods to capture meaningful data from the home environment with automatic sensors and provide an effective method to store and access that data.
- The context-aware persuasive technology could support decision-making process during food practices. Also, influence behaviour change related to increase awareness, reflection and long-term engagement. Study the impact of this technology on raising the awareness of the food waste issue.
- Investigate the impact of push notifications on behaviour change with focus on reflection and awareness, and how push notifications could sustain user engagement for better food waste practices.

1.4 Research Questions

This dissertation will focus on answering the following research questions together with their sub questions:

RQ1: Why do consumers waste food?

- Which factors influence consumer decision-making leading to food waste?
- Which factor has the major effect on consumer decision-making resulting in food waste, and how can this factor support the design of the context-aware system?

RQ2: How could persuasive technology help consumers change their behaviour so as to waste less food?

- What impact does easily accessible information about available food in the house have on behaviour change and decision-making process?
- What impact does notification and reminder have on behaviour change and decision-making process?
- How can we determine whether such a technology reduced food waste?
- How can we improve the future design of persuasive context-aware technology that has an impact on behaviour change?

1.5 Contributions

As a part of a research effort in the field of human-computer interaction to produce creative context-aware and persuasive technology, this research focuses on investigating the impact of context-aware persuasive technology on behaviour change and decision-making process about food. This technology could have an influence on food waste and promote a sustainable lifestyle for long-term. The main contributions of this thesis are classified below:

Food waste causes: Identified the factors influencing consumer decision-making leading to domestic food waste. Once factors identified, investigate how the new persuasive technology could trigger the major factor that produces a large amount of food waste.

Impact of the new persuasive technology on behaviour change: It was discovered that simple availability of data collected was not sufficient to change consumers' behavior, but a system that provided notifications and reminders had some influence. Also, determined how

users could apply this proposed technology to improve their knowledge of planning, buying, storage, and consumption practices to change behaviour and influence food waste.

Impact of notifications on behaviour change: Discovered the impact of notifications on behaviour change and process of decision-making. Also, determined if notifications could improve waste outcome and encourage consumers to use the new persuasive technology on a daily basis.

1.6 Thesis Structure

Chapter 2 Literature Review: This chapter presents an overview of food waste, consumer behaviour, sustainable HCI, behavioural change models, and persuasive technology in human-computer-interaction. In addition, it presents different kinds of previous persuasive context-aware technologies, and engagement methods. This chapter also covers the history of existing interventions that reduced food waste and how these interventions target food when it becomes waste, as well as the role of sustainable HCI.

Chapter 3 Methodology: This chapter introduces the concept of applying HCI to persuasive technologies. It describes the thesis methodology and explores the methods used and the reasons for using each of them to answer research questions.

Chapter 4 Key Factors Resulting in Domestic Food Waste: This chapter presents causes behind domestic food waste that influence decision-making process and how behaviour change theory could identify those causes.

Chapter 5 First Prototype: This chapter aims to investigate if the new technology built (context-aware persuasive technology) could help consumers to change their behaviour. In addition, it addresses how this technology helps users to influence the process of decision-making related to food practices. It also presents design and build of this technology as well as a user interface design.

Chapter 6 FridgeReminder Design for Long-Term Behaviour Change: This chapter integrates the findings from Chapter 5 by improving the design of the previous prototype. It

also presents the design and evaluation of EyeFridge, a passive context-aware persuasive technology that pushes information to users through FridgeReminder. This technology encourages consumers to initiate engagement and behaviour change through facilitates their awareness and reflection allowing investigating the impact of context-aware prototype on decision-making process.

Chapter 7 Conclusions: The final chapter presents further discussion of the contributions and answers research questions. In addition, it highlights limitations and open areas for future work. Following this chapter, several appendixes provide the study material in this thesis study including recruiting emails, consent forms, focus group, individual interviews, and study instruction.

Chapter 2 Literature Review

This chapter presents the literature review of this thesis. The first section covers the literature review of food waste, its impact on environment and communities, the causes of food waste and how to reduce food waste. The second section explores the behaviour of users, factors influencing behaviour such as engagement, awareness and reflection. Also, this section covers the impact of technology and sustainable design on behaviour, existing interventions that reduce food waste and behaviour change models with particular focus on Stern's (2000) value-belief-norm model. The third section defines different context-aware systems with focus on push information. The fourth and final section explores sustainable HCI and how to build effective technologies to better food practices.

2.1 Food Waste

2.1.1 Environmental and Economic Food Waste

Reducing food waste is a universal problem that has gained attention in recent years. Food waste directly or indirectly affects different areas of society, including the economy, environment, food security, and land availability (Kaiser, 2011; Gustavsson et al., 2011; Quested et al., 2013; Halloran et al., 2014). Previous research indicates that one-half of the global food becomes waste, while twice as much food is produced globally as required by nutritional needs per living person (Gustavsson et al., 2011; Fox, 2013). The majority of food waste ends up in landfills, and once in landfills, decomposition releases methane gas into the atmosphere and contributes to global greenhouse gas emissions, which add approximately 8% to total global greenhouse gas emissions each year (Wang et al., 1997). This contributes to the global warming effect and increases the need for land estates to house exhausted landfill capacities.

The recent report from the Intergovernmental Panel on Climate Change indicates that global food security is under threat (IPCC, 2013). Food security is the ability for countries to their wasted food supplies to feed their nations. The access to food supplies is a growing concern; it has become threatened because of a dwindling nutritional food supply (Maxwell and Smith, 1992). In addition, climate change has an impact on sustainable environment and wasted resources caused by flooding, which is becoming more prevalent and impacting the ability to grow seasonal crops and thus is influencing global food production. Shifting climates become a risk to food security if the facets of food processing, storage, consumption, and waste processing are not managed more efficiently. This also presents a risk to sustainable food growing, access, nutrition, and distribution (Maxwell and Smith, 1992; Lawrence et al., 2010).

An increasing awareness of the ecological, social, economic, and health-related implications of food waste has resulted in the offering of information to people affected by the impact (Kantor et al., 1997; Griffin, Sobal, & Lyson, 2008; Parfitt et al., 2010). Nevertheless, Heller and Keoleian (2000) explore that many food systems are not ecologically, economically, or socially sustainable. Therefore, we need to identify how and where wastages occur to reduce food waste and the impact of food waste on communities.

2.1.2 Food Waste Impact

Food waste occurs during growing or harvesting for distribution or during post purchase when individuals fail to meet processing and selling requirements. Food waste happens during the supply chain process (for example, during the growing stage, not all food is chosen for edible consumption; thus some food is not distributed to retail). During the processing stage, food that is damaged or blemished is not selected for sale because consumers believe that blemishes or bruising are signs of spoilt food (Green & Vergragt, 2002).

Many actions have focused on food management alterations through agricultural, processing, hospitality, and food retail modifications (Kantor et al., 1997; Parfitt et al., 2010). More actions, such as marketing ploys designed to encourage consumers to purchase products close to expiry to reduce food waste (Tsiros and Heilman, 2005), have targeted food retail

marketing. These studies demonstrate that food waste occurring during production, procurement, processing, and dissemination in the food supply chain process are being addressed in various ways. However, domestic settings, where food waste is most prevalent, are still under investigation.

Ambler-Edwards et al. (2009) explore that the majority of food waste occurs in domestic surroundings. However, Kantor et al. (1997) suggest that it occurs in food retail outlets. Caswell (2008) argues that the average consumer's annual household waste will contain between 40% and 60% of food waste in the UK; once this waste is collected, it is commonly deposited in landfill. Wade (2011) suggests Australian household waste contains almost 20% of landfill capacities. Kantor et al. (1997) recognize that the amount of household waste in US households include food that was forgotten and had expired in storage. Schneider and Obersteiner (2007) acknowledge that preparation residues and leftover foods were contributing 30% and 18%, respectively, to overall household food waste in Europe. Schneider and Obersteiner (2007) argue two-thirds of domestic food wastes are preventable. This information presents the initial motivations for this study to target reduced domestic food waste and is subsequently supported in contrast to 25% of the annual global edible food supply being wasted (Schneider, 2008). To put this figure into perspective, Wenlock et al. (2008) discuss that wasted food comprised approximately 4% of the total household waste in the 1980s. The percentage of wasted food in household waste had subsequently risen to 22% in 2008, and even higher at 25% in 2012 (Gunders, 2012). Overall, more food is being wasted.

Gustavvson et al. (2011) state that developed countries are mostly responsible for food waste. These countries produce 40% of all food waste, mainly from the household consumer and retailer level. The remaining 60% of food waste is created throughout food production, harvesting, post-harvesting, and processing (Parfitt et al., 2010; Godemann and Michelsen, 2011). Moreover, ethical implications that accompany food have an effect alongside ecological effects. It is significant to highlight that for consumers, food waste usually happens inadvertently. Evans (2012) and Ganglbauer et al. (2013) studied that participants did not want to waste food. Food was wasted unintentionally along with ethical and economic concerns.

However, to measure quantities of wasted food, food waste and what it contains must first be acknowledged. Schneider (2008) explores that food waste can be identified in four ways: (i) the original consumable food, (ii) a partly consumed or used food, (iii) leftovers, and (iv) inedible preparation residues. Some of these wastes are expected outcomes of consuming food. For example, inedible preparation residues are the outcome of consuming a specific product. However, the remaining states of food waste, such as the original food, partly consumed or used food, and leftovers, are preventable (Schneider & Obersteiner, 2007). This presents an opportunity to explore design interventions as a way of assisting in their prevention.

2.1.3 Behaviours Resulting in Domestic Food Waste

A number of considerations, such as consumer behaviours, can lead to food being wasted. The majority of domestic food waste is the result of consumer behaviours. These behaviours are promoted by various influences occurring during the process of food planning, purchasing, storage, cooking, and consumption. In addition, incorrect and misinformed knowledge can drive particular behaviours that result in food waste. This includes the ambiguity regarding consumer understanding of expiration dates. For example, Green et al. (2003) indicate that food quality, sustenance, and nutritional value are measured by food's appearance, which often associates bruised and blemished products with tainted food. In their study of Australian consumers, Dixon and Isaacs (2012) discovered a discrepancy between desire and actual behaviour of consumers. They identified that consumers are able to associate the nutritional value of food with how fresh it is. However, consumers are more likely to purchase processed foods that are cheaper, create less waste, and are preferred by their children. Further, a variety of different conditions of a person's lifestyle can also impact on conditions that promote behaviours resulting in domestic food waste (Schlegelmilch, Bohlen, & Diamantopoulos, 1996; Young et al., 2010). This can promote apathetic consumer purchasing behaviours, which are reflected in bulk purchases and are due to products often being cheaper when bought in bulk. However, consumers mostly do not consume the whole amount of bulk purchased. The excess unused food will likely expire and be discarded as a result, without having been consumed (Godfray et al., 2010).

Disposing food is a common practice once food reaches its expiry. It is then subsequently replaced with a fresher product. Recently, this has commonly become a common practice for people in the developed countries that have continued because of the overproduction of food. Food overproduction is a major contributor to global food waste (Darlington & Rahimifard, 2006). Overproduction in the developed world is met with marketing ploys utilized by centralized food distributors, and it is delivered to consumers through several different marketing techniques (Vermeir & Verbeke, 2006). For example, marketing ploys encourage consumers to purchase food in bulk to save on the cost of buying a similar quantity of the single product. This encourages consumers to purchase food in large quantities because it is cheaper to do so (Kader, 2004). Often a quantity of food remains unconsumed before reaching expiry and is in turn discarded. Furthermore, special offers are another marketing technique utilized to encourage consumers to purchase items they may not need. Baumeister (2002) and Ene (2008) explore the reason behind over-purchasing food: consumers are under the influence of marketing ploys to purchase food spontaneously, regardless of the cost to buyers. This can also encourage purchases of food already in a consumer's household and may lead to consumer stockpiling. It raises the possibility of foods being forgotten (Kantor et al., 1997), and as a result it may lead to their expiration. This emphasizes the awareness of available food and the environmental impact of the actions of the household when shopping for groceries.

The Consumer Purchasing Behaviour Model (Jager, 2000) can be used as a mechanism to predict and understand consumer-purchasing behaviours. The model depicts three factors of behaviour intention for an individual in a given situation, and consumer action is dependent on both attitude and behaviour. These factors are:

- Values, attitudes, and motivation.
- Information and knowledge.
- Behavioural control.

Vermeir and Verbeke (2006) extended the Jager (2000) model to include a mechanism that explained how attitude would be affected by the following factors:

- Involvement and values of consumers

- Consumer's uncertainty surrounding information
- Knowledge of products and how they link to sustainability
- Behavioural control that is demonstrated in perceived availability of products
- Perceived consumer effectiveness

This model can be used to inform a better understanding of consumer decision-making during food purchasing. Tsiros and Heliman (2005) explored methods for industry to support reduced food waste through investigating consumer behaviours related to the effect of expiration dates. Their findings indicate that the majority of consumers need to increase their awareness of food expiry dates. This should inform shoppers about accidental purchases of products that are about to expire.

Several factors have positive impacts on sustainable behaviour around food practices: education, price, gender, gardening and living with a family that cares about sustainable lifestyle (Brunner et al., 2007). Sometimes values, attitudes, and intentions have a positive impact on sustainable food consumption and disposal but do not always translate in daily practice. This is called the intention-behaviour-gap (Vermeir and Vebeke, 2006). Vermeir and Vebeke (2006) studied the buying practice of sustainable food products in a laboratory and suggest factors that can promote consumption choices regarding organic products and therefore support overcoming the intention-behaviour gap. These factors include involvement with sustainability, perceived availability, and perceived consumer effectiveness. The only limitation of this study is that it should carry out in the field, as it does not capture the entire procedure that consumers experience during purchasing food.

Food wastage, occurring at later stages in the supply chain, the retail and consumption stage, are referred to as food waste. Food waste is the amount of edible food, which is discarded. This includes Stuart's (2009) definition that argues that food originally intended for human consumption, which intentionally has not been used to this end, should also be considered waste.

How well an individual manages and plans their food consumption is strongly associated with their awareness and knowledge of problems and solutions. One example may be presented by consumers' lack of awareness and knowledge about date labeling.

According to Aschemann-Witzel et al. (2015), consumers often misinterpret date labels. If consumers are using date labels as indicators of food safety instead of as an indicator of freshness, they may tend to discard food, which is still edible. Furthermore, date labels are not consistently defined. Thus, different labels, such as “best before” and “use before”, may indicate various characteristics. Also, these definitions can vary across suppliers, brands, and food categories. This lack of knowledge and awareness may cause individuals to apply labels wrongly and thus throw out food, which is still edible. Another example relates to suboptimal foods. An individual’s lack of awareness or knowledge concerning the evaluation of food safety may facilitate food waste. In other words, due to their lack of knowledge an individual may evaluate food safety on basis of aesthetic standards. For example, people may discard potatoes growing sprouts or apples turning wrinkly out of fear they have turned bad even though they are still edible.

Vermeir and Verbekev (2006) argue that everyday purchasing and consumption practices are heavily motivated by a variety of situational influences such as convenience, habitual behavior, health concerns, perceived value for money, lifestyle, and social responsibility perceived through social norms.

Cooking and/or eating are activities that connect family members or let friends have a great time together (Grimes and Harper, 2008). Quist et al. (1998) suggest several factors that can influence a person’s behaviour towards cooking: the timing of meals eaten, the type of meals eaten, the consumption of ready-made packaged meals and unprepared food, how well a consumer is organized to take sufficient time for grocery shopping and cooking, how much food is purchased, and whether they grow their own food. In order to reduce the impact of these behaviours on food waste, new methods, approaches, and strategies of prevention must be explored.

Storage practice in domestic settings is a vital component in preventing waste consumption. Kantor et al. (1997) identified that portions of household waste comprised food that was forgotten and had expired in storage. However, very little research has targeted food storage to assist consumers in utilizing food before expiry and in locating forgotten items. The variety of reasons why food storage may promote behaviors and practices that drive food

waste need to be investigated and identified, to explore how to influence behaviors driving their domestic food wastage.

This thesis focuses on planning and purchasing practices by avoiding over purchasing and technology opportunities arisen towards these practices. This is due to the fact that consumers face a problem of retrieving (for example, remembering what they have inside the fridge or what to prepare for meals) which is one of the factors identified later in Section 4.4. As will be discussed in Chapter 4, consumers are willing to change their behaviour toward more sustainable practices around food, but they do not know how to translate their intentions into better everyday practices and choices. This work is different than previous research by targeting everyday consumer behaviours (everyday food practices). According to Schneider and Obersteiner (2007), two-thirds of domestic food waste could prevent by impacting these behaviors. To impact consumers' behaviors, factors result in domestic food waste should be identifies. However, previous research identifies factors that could not be changed during purchase practice such as price and gender (Brunner et al., 2007).

2.1.4 Reducing Domestic Food Waste

Recently, wasted food produced from British households has decreased. Between 2007 and 2010, there has been a decrease in the amount of wasted food from 8.3 million tonnes to 7.2 million tonnes (Wrap, 2011). The WRAP presentation program helped with this decrease in waste. It involved several partners including food retailers, food and drink manufacturers, local authorities, and community groups. This also linked with increases in food prices and challenging economic conditions.

Schneider and Obersteiner (2007) propose that the behaviour that leads to prevention of domestic food waste is influenced by numerous factors, such as age, income, and time spent at home. Moreover, situational circumstances also affect individual behaviours that result in food waste; these include smell, appetite, desire for food, and product marketing (Schneider, 2008). Schneider (2008) suggests numerous approaches to reduce food waste that could be used in households: creating a shopping list, measuring food portions by using highlighted tabulated measurements, creative thinking of unwanted food, educating household members

about the financial value of wasted food, and everyday food waste awareness (Schneider, 2008).

Quested et al. (2013) indicate two ways to reduce domestic food waste: (i) influencing individual behaviours, and (ii) changing the way products are sold in retail (for example, extending shelf life, changing packaging, and altering how it is sold). FUSIONS (food use for social innovation by optimizing waste presentation strategies) was set up to work toward a 50% food waste reduction produced in the EU and a 20% reduction in food chain supply by 2020 (EU committee, 2015). The United Nations environment program has arranged potential targets for raising consumers' awareness on the food value they eat, as well as the environmental impacts of their choices, with focused to redirect consumption patterns to less resource-intensive foods (Moomaw et al., 2012). Brynjarsdttir et al. (2012) explained that changing behaviour into more sustainable actions is commonly assumed as reducing individual resource consumption without outlining the planned behaviour change.

Therefore, the literature gap that this thesis addresses is: Why do consumers waste food? (RQ1). However, identifying the key causes of food waste is only part of the problem. Once the causes have been identified, steps can be taken to influence the causes and thereby encourage a change in people's behaviour. This is will be addressed in Chapters 5 and 6.

2.1.5 Food Sharing

Another method to reduce food waste is by sharing food—this method has been used for decades. For example, food bank establishments offer food to those who need it instead of throwing it away. Some organizations offer additional benefits to their members to increase community engagement in educating members. One such organization is casseroleclub.com, which is a social community that connects people who cook with people interested in cooking to increase social engagement and reduce malnutrition. New technological developments have focused on sharing food practices. For instance, Ganglbauer et al. (2014) studied how signing up for the FoodSharing.de platform enhances the ability to reduce food waste in Germany through sharing food amongst consumers, farmers, organizations, and retailers. The results indicate that over 17,000 users that signed up for the FoodSharing.de platform

successfully facilitated the sharing of food. Moreover, sharing food platforms brings communities together, whether it is for social interaction or entertainment (Grimes and Harper, 2008; Wei and Nakatsu, 2012). Foster and Lawson (2013) built the Shareyourmeal platform that allows people to share leftover home-cooked meals with their neighbours. They found that this platform has a high potential to change behaviour; however, they did not investigate the impact of social strategies on food waste.

Figure 2-1. Foodsharing.de platform from Ganglbauer et al. (2014)

2.2 Context-Aware and Persuasive Technology

2.2.1 Defining Context-Awareness

The position of context awareness for better decision-making has been a topic of interest over the last years (Brezillon, 1998; Brezillon, 1999). The more vague the decision situation, the better benefit from context awareness to provide the user with information to better understand the decision parameters and implications of choosing one of the suggested decisions. The majority of real-time decisions are based on accessing real-time data that can help with the decision-making process. Real-time decision-making involves establishing

system architectures, which helps with system infrastructure for wireless connection (Padovitz et al., 2004) and network security (Allen and Wilson, 2002).

A recent definition of context-awareness described it as knowledge and understanding of the near surrounding that is operated within the decision support system. Context-aware systems are a component of a ubiquitous computing or pervasive computing environment. It is essential to provide the decision-maker with full information based on the best possible context model within the setting of real-time decision support (Brezillon, 1998; Padovitz et al., 2004). Examples of context characteristics are available bandwidth, last completed transaction, or approximate time to get a patient to a hospital where they will receive the best care (Padovitz et al., 2004). Context includes the user's location, collection and sensing of the surrounding environment, nearby devices, and changes to these entities over time. Thus, context data is commonly used and active (Heer et al., 2003). It may contain lighting, voice, wireless connection, available bandwidth, and social circumstances. Context is a set of implicit or explicit motivations near an individual, and it consists of the physical or social environment that could disturb behaviour, and the implied context that refers to psychological conditions acknowledged through some type of implication (Davis et al., 1988). Abowd & Dey (1999) identified three significant context-awareness behaviours that an application might present:

- Information presentation and services to a user
- Automatic execution of a service
- Tagging information for later retrieval

2.2.2 Defining Persuasive Technology

A recent trend in computing is to develop persuasive technologies (Fogg, 2003) to help people change their everyday behaviors in support of the lifestyle they wish to lead (Consolvo et al., 2008; Gasser et al., 2008). The quest for changing attitudes or behavior is also the topic of a field known as *Persuasive technology*. The field was first introduced by Cialdini (1993) and has since developed into a field of research, primarily within the information technology industry. Fogg (2003) defined persuasive technology as "an

interactive product designed to change attitudes or behaviors, or both, by making a desired outcome easier to achieve".

Since 2003, there were many research regarding this subject has contributed to our understanding of designing persuasion by means of technology. As a result of this wide interest in the subject, we can more clearly see how to match target behavior to relevant theories and techniques, how technology offers a means to create a person's persuasion profile, and how different forms of feedback relate to effective behavioral change.

2.2.3 Context-Aware Technology, Persuasive Technology and Behaviour

Researchers in context-aware believe that context is important in their works to scatter and clearly merge computer technology into individuals' daily lives (Chen, 2003). The main aim of context-aware computing is to obtain and apply context information about a device to deliver services and assist users during decision-making process that lead to changing their behaviour. Chapters 5 and 6 addresses context awareness by means of sensor data (images) captured within the fridge.

Fogg (2003) stress that persuasive technology should not forces the user into certain behavior. Fogg describes strategies for persuasion according to their function, and has identified seven of them: *Reduction, Tunneling, Tailoring, Suggestion, Self-monitoring, Surveillance* and *Conditioning*. In addition he points out that technology can persuade on two levels. If the sole purpose of the product is to persuade, it is persuasion on a macro level. If persuasion is incorporated as an element in the product, it is on a micro level (Fogg, 2003).

Brynjarsdottir et al. (2012) state a need for persuasive technology to be used in a behavior change process. However, consumer's environment must be considered in the design process, this is due to behaviors are different between individuals (Spangenberg & Lorek, 2002), and different contexts may stimulate different behaviors in individuals (Brynjarsdottir et al., 2012).

Persuasive technology has become one of the key trends in HCI that can motivate individuals, groups and society to engage in behavior change. Persuasive technology

proposes that designers should focus their influential potential on those who are already motivated, facilitating their paths to goal fulfillment. Thus, this thesis addresses how can we entice consumers to be engaged in intended a long-term behavior change process. The following section (2.2.4) explains the potential for notifications and reminders to fill in this gap.

2.2.4 Notifications and Reminders

Mobile phone notifications notify and update users regarding different events (for example, receiving a new text, a new update of an app, or a reminder to re-engage with an app after a period of non-use). Some notifications, such as application update, show mutely, whereas others, such as incoming short messages, ring, vibrate, or create a brief visual to capture the user's attention. Some users take instant action after getting these notifications, while other users ignore based on the importance of the notification and/or the user's present situation. Notifications have been described as a visual cue, auditory signal, or haptic alert created by an application or service that sends information to the user (Iqbal and Horvitz, 2010).

The way notifications are presented offers a unified mechanism on current modern smartphones. The notification quickly appears on the notification bar located at the top of the screen. These notifications are commonly used by a wide variety of mobile applications. The notifications have a diverse nature; some applications use the notifications lightly, while other applications send many notifications.

Nevertheless, earlier research has shown that users value notifications. Iqbal et al. (2010) examined how participants valued the awareness offered by the notifications. The results also show that users are curious about notifications received, as they frequently check their phones (Oulasvirta et al., 2012).

Thieme et al. (2012) was the first who proposed reminders in the sustainability area. However, mobile notifications were never proposed before in the sustainability domain, and in particular, for interventions that help reduce food waste. In another study, Fogg and Adler (2009) mostly focused on SMS messages as reminders, as they were pervasive at the time on all mobile devices. Their focus was on active notifications that would generate visual cues or

auditory signals to get the user's attention. The focus in this thesis is on passive notifications and the impact on behaviour change and decision-making process. The effects of notifications on reflection and awareness were investigated as part of the research presented here. This is the topic of Chapter 6.

2.3 Consumer Behaviour

Previous technology interventions that have required users' behaviours to be influenced have gone through different challenges; some have successes while others have failed to meet expectations. Hadfield-Hill (2012) argues that various difficulties are encountered in overcoming pro-environmental behaviour. Increasing users' interests and behaviours toward sustainable food practices does not mean changing their behaviour regarding food waste (Vermeir and Verbekev, 2006). This is because external factors could stop users from performing and supporting such practices. The most successful method to encourage change in environmental behaviour requires different type of intervention, which targets factors that have an influence on users, such as employing religious methods that attract individuals' morals and influence their opinions, offering feedback to change users' behaviours, rewarding desired behaviours and punishing undesired behaviours, and offering a shared understanding of guidelines and expectations within community management (Stern, 2000). However, intervention should aim to eliminate any difficulties preventing the change process and must be personalized to the user's condition to guarantee the most comfortable transition into changing behaviour (Stern, 2000).

Meulenberg (2003) argued that sustainable food practices are established in a decision-making process that engages users in their different desires and needs as well as their perceived social responsibilities. That make users feel a social responsibility and pressure to make decisions based on their observation of sustainable food practices. Everyday food practices such as shopping and consumption are deeply inspired by different situational encouragements (for example, lifestyle, suitability, regular behaviour, diet and health concerns, perceived value of money, and social obligation) (Vermeir and Verbekev, 2006). However, even these influences are still resilient to change (Dawson, 2000; Tucker and

Douglas, 2007). This shows some difficulties in influencing behaviour change directly and emphasizes the desire to study and influence other external factors as well as opportunities to encourage more sustainable behaviours that result in reduced domestic food waste.

2.3.1 Behaviour Change Models

Understanding the behaviour of individuals in terms of social psychology helps us to understand the reasons why individuals behave the way they do and recognize the specific factors that may affect the behaviour. This topic has received attention from researchers over the years, and a large number of models have been developed.

Several theories can explain consumer decision-making behaviour. The theory of planned behaviour (TPB) is a common theory that is used to explain an individual's behaviour by identifying the reasons of behaviour through examining the individual's beliefs, attitudes, and intentions (Ajzen, 2011). However, Stern (2000) argued that the Theory of Planned Behaviour is not successful because it does not accommodate the user's awareness and ability, and therefore it is insufficient for determining the impact of such indicators. Also, a number of external factors are not included in the Theory of Planned Behaviour model to support behaviour; these include community expectations, advertisement, marketing, and public policies.

Attitude-Behaviour-Context (ABC) theory (Guagnano et al., 1995) indicates that behaviour (B) is formed by personal attitudinal variables (A) and contextual factors (C). This means that attitudinal factors are able to predict behaviour when contextual factors are neutral and approach zero. However, this theory does not include consumer knowledge and skill for particular behaviours.

Other models, such as the Theory of Interpersonal Behaviour (Triandis, 1977), the Motivation Opportunity Ability Model (Thøgersen, 1995), and the Comprehensive Action Determination Model (Klockner and Blobaum, 2010) include a larger variety of factors, increasing the potential accuracy and granularity of describing the actual situation, but also making the models more complex to apply. Jackson (2005) argued that this as a reason why

the Theory of Interpersonal Behaviour has been used less frequently even though it appears to have additional explanatory value.

In this thesis, the value-belief-norm theory has been chosen as part of the data collection and also to analyse the data collected. The value-belief-norm (VBN) theory of environmentalism (Stern, 2000) is a conceptual framework to explain environmentally significant individual behavior and found to be useful to study the influence of consumer decision-making behaviour related to food waste practices. The VBN theory of environmentalism provides a formula that examines the causes of behaviours related to nonactivist environmentalism (Stern, 2000). This means that VBN theory examines the impact of an individual's behaviour on the environment. To identify the causes leading to domestic food waste, understanding the circumstances that lead to these behaviours should be examined.

There are a variety of variables that influence consumer decision-making. Stern's value-belief-norm (VBN) theory (Stern, 2000) provided a framework for investigating behaviour that leads to food waste, and for studying behavioural changes to help reduce food waste. These four casual variables are:

- Attitudinal factors include an individual's values, beliefs, and attitudes. Examples are individual's environmentally behaviours.
- Contextual forces include advertising, interpersonal influences, the ease or difficulty of particular actions, community, social, and political expectations. Examples are buying three for two or unexpected events.
- Personal capabilities include knowledge, available time and money, social status, and power such as expiry date.
- Habits or routines are actions established from an individual's everyday practices such as writing a shopping list or checking the fridge content before shopping.

According to Stern (2000) different combinations of these variables could influence individuals' behaviour in different ways. For example, *external forces* variable could influence behaviour when changing plans to have dinner out with friends instead of home cooking. These variables will be employed to understand the causes influencing consumer decision-making leading to food waste. This theory has been used in this thesis to study and

understand users' food and food waste practices to identify causes. Once these causes are identified, this helps with encouraging behaviour change. Table 2-1 illustrates the environmentally significant behaviours and VBN's causal variables influencing these behaviours.

Causal variables	Environmentally significant behaviour
Attitudinal factors	Environmental activism
Environmental attitudes	Policy support
Non-environmental attitudes	
Believes and norms	
Contextual forces	Behaviour affecting consumer's planning and purchase decisions
Product costs and rewards	
Marketing and advertising	Waste disposal behaviour
Available technology	Fridge size
Social norms and expectations	Changes in lifestyle
Laws and regulations	
Personal capabilities	Consumer purchase behaviour
Social status	Maintenance of household equipment
Literacy	Waste disposal behaviour
Financial resources	Consumer's good memory
Knowledge and skills	
Habits or routines	Significant behaviour change
Planning in advance	

Table 2-1. Major types of environmentally significant behaviours and casual variables influencing these behaviours (Stern, 2000)

2.3.2 Engagement

The range of HCI and associated fields have theorised engagement extensively. Much misunderstanding occurs about what establishes engagement, as it is frequently used with

participation, involvement, and attention. Engagement in HCI ranges from the broad indicator of the quality of interaction to the cognitive measure of attention (Peters et al., 2009).

Engagement has also been involved in learning and education as the 'physical and psychological effort' dedicated to a job (Astin, 1984). Significantly, engagement has quantitative and qualitative characters that impact on the usefulness to help users accomplish their targets. Physical effort relates to behavioural engagement, and psychological effort relates to cognitive engagement.

The idea of psychological effort has been broaden investigated in HCI research in terms of flow or optimal experiences (Csikszentmihalyi, 1997). Flow experiences happen when an individual is fully engaged in a task. This engagement is not a significant effort and is fundamentally motivating. While flow characterizes optimal experience, it would not be predictable to happen through on-going activity, such as waste disposal. Flow experiences could also limit self-reflection, which relates to intrinsic engagement.

The recent studies in HCI research have moved the attention of engagement to understand it as a significant interaction that individuals have with a product or service. This significant interaction developed into a serious factor in third-wave HCI (Bodker, 2006; McCarthy et al., 2006) and ranges outside affective engagement. The conclusion of this study is that engagement is significant reflection on activity in experience (Dewey, 1997). This reflective engagement includes a serious reflection on sustained activity, thinking over and throughout the present actions.

This thesis, however, addresses the gap on how to initiate interaction with persuasive technology for a long-term behaviour change and promote food waste reduction. The long-term behaviour change could lead to increase self-knowledge, reflection and awareness of food waste. For the purposes of the work reported here, engagement is defined as engaging the user with the technology, and determining how added features could promote long-term behaviour change to improve food practices. This will be addressed further in Chapters 5 and 6.

2.3.3 Reflection and Awareness

Reflection is an important aspect in the HCI research; it ranges from increasing self-knowledge through personal informatics, to changing behaviour through persuasive technologies. Reflection could possibly provide suggestions within data examination or discussion. As Baumer et al. (2014) explained:

Sometimes the goal of reflection is not only to increase self-knowledge but to take action based on this increased awareness. Systems of reflection vary as to the extent that they support taking such action [Baumer et al., 2014, p.96].

Fleck and Fitzpatrick (2010) labelled reflection level as *"transformative reflection"*, particularly reflection with intention to change. They studied several definitions of reflection that have various purposes and present different levels of reflection. These levels are (Fleck and Fitzpatrick, 2010, p. 217):

- *Description (R0):* Reportive account or statement about experiences and things without further explanation or reflection.
- *Reflective description (R1):* Reportive in nature with explanation or justification of reasons and experiences, without further reflection.
- *Dialogic reflection (R2):* Exploring different relationships between experiences and knowledge and considering different explanations or other viewpoints.
- *Transformative reflection (R3):* Revisiting experiences with the intention to change, reorganize or do something differently. Challenging personal assumptions and practices.
- *Critical reflection (R4):* Reported experiences are related to wider social and ethical implications. Considering the bigger picture and implications.

These levels could be applied in different domains; thus, they increase self-knowledge or changing behaviour. Reflection in-action is the reflective practice performed while doing an activity to enhance instantly the upcoming action (Schön, 1987), and reflection on-action is defined as the reflective practice performed when the activity is completed to review the situation for improved practice in the future.

In similar research with that conducted regarding food waste, Ganglbauer et al. (2014) established two different forms of reflection in the use of a food waste diary. These are reflection-through-recording when manually entering data. The other form is reflection-through-revising when data has been submitted. The focus in this thesis will be on reflection-through-revising because the technology will sense the data and turn it into a visual form, with no need of the user to enter data manually.

The aim of reflection is to increase self-knowledge and also to take action based on this increased awareness. Systems that support reflection differ depending upon the action required. Malacria et al. (2013) explained that some systems recommend particular actions that users would undertake, while other systems leave the user in control to take an action. These systems are called system-driven and user-driven in personal informatics systems (Li et al., 2010). Li et al. (2010) discovered that the only limit through the action phase was a lack of alternative recommendations provided to the user to help translate the outcome of reflection into action. Nevertheless, only a few systems suggested certain actions after reflection. Some intervention methods, such as mobile devices or computer systems, support reflection (Gongora, 2012; Grimes et al., 2010) or public installation (Hebert, 2009; Valkanova, 2013).

This thesis aim to increase reflection and awareness through persuasive context-aware technology to change behaviour and influence decision-making process. For example, raising reflection through raising awareness of available food in the fridge through the images online and notifications received. This increase in awareness and reflection will ultimately lead to long-term behaviour change, as discussed earlier in section (2.2.3).

2.3.4 The Impact of Technology on Consumer Behaviour

Food waste reduction can be achieved through technology and human-computer interaction concepts. Studies have shown that users prefer environmentally friendly options (Autio and Wilska, 2005). This result is significant with respect to the impact of food waste on the environment.

Blevis (2007) and Fogg (2002) argued that HCI methods support behaviour change development. Bishop (2005) investigated the efficiency of some motivational methods for example rewarding, emotional motivation, intrinsic motivation, gamification, and goal setting. However, maintaining changed behaviour over the long term has been a challenge. The user experiences an early interest and motivation to change behaviour, but the interest fades away over time due to several reasons. These reasons are the user's lifestyle, free time, and further external factors (Jackson, 2005). Moreover, Blevis (2007) discussed that HCI research must study the added impact of interaction and engagement into technology to encourage behaviour change.

Several interventions have targeted domestic settings, specifically aiming to provide support for people to undertake tasks associated with their everyday lives, with tools such as the Smart Fridge. The purpose of Smart Fridge was to offer Internet and multimedia access to help users with browsing the Internet; control household appliances, such as the oven, while the users are on the move; and manage food supply stocks (Chi, Chen, Liu, & Chu, 2007). The user interacted with Smart Fridge through a touch screen located on the front of the fridge door. However, Smart Fridge technology did not achieve success in the market due to several reasons: (i) the Smart Fridge technology had hidden benefits to its users compared to the benefits of the traditional refrigerator (Halupka, 2012; Lueg, 2002), and (ii) the Smart Fridge (Alolayan, 2014) was expensive. This result offers further possibilities to analyse interventions that could overcome difficulties associate with innovations such as the Smart Fridge.

Technologies are noticeably involved in daily practices. Technology interventions could make a change in consumer behaviour and also could support and promote practices resulting in food waste reduction. Food waste has an impact on the environment and also an impact on greenhouse gas emission. However, designers should be careful when designing such technologies and integrate these technologies into everyday life. Parallels have been found regarding the design of technology and the design of policy to promote change in daily practices. Warde (2005) claims that social practice theories suggest that policies must study the position of individuals in the practices undertaken. A gap is found between individual values and actions—it is called the intention-behaviour gap: *"policy must be sensitive to the*

everyday contexts in which individual intentions and actions are constrained by socioeconomic and political institutions" (Blake, 1999, p.274). Dourish (2010) explains related concerns about how to integrate technologies into contexts and everyday practices. Therefore, it is important to understand food practices and how daily practices are involved or not involved in food waste to design future interventions.

2.3.5 Existing Interventions to Reduce Food Waste

Numerous strategies and creative ways have been found to reduce and manage food waste (for example, using food waste as animal feed) (Darlington et al., 2009; Tsiros & Heilman, 2005). Nevertheless, domestic food waste is generally unrestrained—notwithstanding many public and private challenges to reduce it by applying new approaches such as raising food waste awareness, behavioural modification, and intrinsic and incentive motivation (Bucci et al., 2010; Thieme et al., 2012). However, HCI researchers have studied many interventions targeting these approaches. The intervention proposed later in Chapter 5 and 6 is based on Thieme et al. (2012) work. They developed BinCam, a ubiquitous technology that took photos of food waste from inside of the bin and then uploaded them to a dedicated Facebook page to allow users to reflect on the photos taken. This technology focuses on food when it is wasted but the intervention proposed in this thesis focuses on preventing food before it turns into waste. Bucci et al. (2010) studied a fridge that sent SMS or email alerts to users about products expiring soon, suggested recipes, generated shopping lists, and posted messages to family members. However, the researchers did not propose the design for such an intervention. Gartland and Piasek (2009) established a new interactive disposal bin called "Weight your waste," which had an integrated scale to weight the quantity of food waste, its financial costs, and information on how to reduce food waste. This information was visualized to the users with emphasis of the financial benefits of reducing food waste and the resulting environmental benefits. Lim et al. (2014) developed the EUPHORIA system, a community social system that tracked users' food waste and promoted behaviour change. The system suggested recipes based on available food in the fridge. However, the researcher did not evaluate the impact of this project in user's pro-environmental behaviours, although the design has a promising concept. These interventions failed to meet expectations in

sustainable change behaviour because individuals did not accept these new technologies (Davis, 1989) and none of these interventions target food before it turn to waste.

Farr-Wharton et al. (2012) studied the colour code scheme in the refrigerator to reduce food waste by increasing awareness of available food location for all household members. Clear et al. (2013) studied cooking practices and how to design interventions related to these practices. These practices involve interactions with cooking appliances, food sharing mobile applications, group inventory management, and interactive technologies.

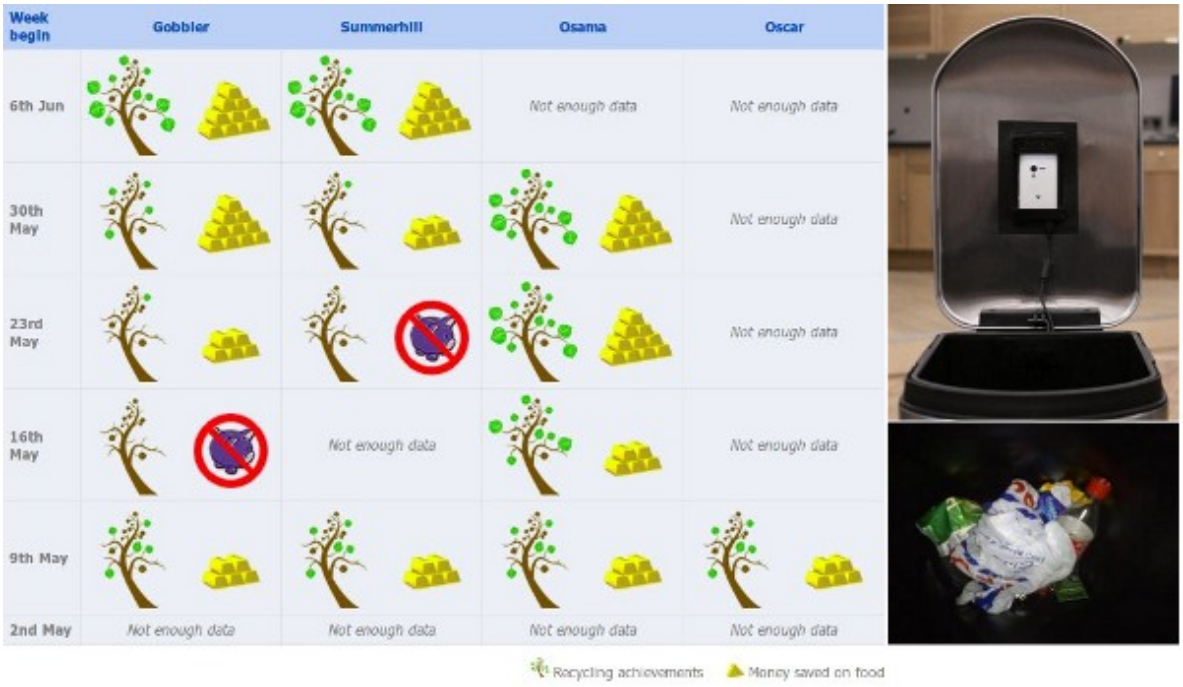

Figure 2-2. BinCam prototype and Facebook app (Thieme et al., 2012)

Moreover, researchers have studied mobile phone development as a way to promote sustainable lifestyles in different areas, such as food and health (Grimes et al., 2008) and transportation (Froehlich et al., 2009). However, these tools support reduced food waste behaviour, but minimal research has been done on the use of mobile phone devices to promote sustainable lifestyles. Moreover, Rouillard (2012) provided mobile application for users that allow entering data of a product manually or scan the barcode using Prixing as an external database. Prixing retrieve the price of a product according to it EAN code/barcode. Rouillard suggested many valuable technologies that might be embedded with future

interventions to support the design of related technologies to manage data, such as image recognition, camera barcode scanner and voice.

Many mobile applications support users with their daily food practices. Some of these applications are designed to help the user with everyday practices undertaken during food purchasing, storage, and cooking. Many organizations have capitalized on opportunities to provide information to users on how to manage food usage by accessing recipe suggestions and a food diary via mobile applications (Ene, 2008; Schneider, 2008). Other mobile applications, such as the LeftOverSwap and Love Food Hate Waste, have targeted raising food waste awareness within communities. In another example, Ganglbauer et al. (2012) built a food waste diary mobile app that provides information to consumers on the amount of food that has been wasted. This mobile app promotes consumer self-reflection through visibility in diverse stages of food practices. Moreover, the app provides information on the reasons behind wasting that food, and then makes the information available to other users to support and promote sharing and natural reflection. Changing behaviours related to food practices and food waste can be difficult; however, using technology could help to reduce domestic food waste. For instance, Lim, Dolech, and Yalvaç (2014) studied a recipe finder application that helps users find new ways of using food instead of throwing it away by delivering knowledge of food usage and alerting users of items nearing their expiration dates. The results indicate that technology can bring people together through shared meal consumption.

Figure 2-3. Love Food Hate Waste app (Wrap, 2013)

2.3.6 The Impact of Sustainable Design on Consumer Behaviour

One of the most interesting contributions to the sustainable HCI literature is the PhD thesis on feedback mechanism by Froehlich (2011). Through a comprehensive investigation of studies in the literature examining feedback mechanisms and their effects, he identified what he called "the eight dimensions of the eco-feedback design space" (Froehlich, 2011, p. 4-8). These dimensions are update frequency, data representation, interactivity, social aspects, display medium, actionability, comparison and motivational/persuasive strategies.

Froehlich states that these dimensions serve three goals: (i) to provide designers with a tangible structure of eco-feedback, exposing assumptions and providing a way of comparing strengths and weaknesses, (ii) to uncover opportunities and provide a structure for exploring possibilities, and (iii) to provide a common vocabulary to discuss and analyse eco-feedback (Froehlich, 2011).

Many of these dimensions are considered to be of vital importance in the development of technologies that facilitate a change in food-related behaviours (Fang & Hsu, 2010;

Froehlich, 2009). While Froehlich's (2009) model was originally developed to encourage shifts in energy consumption patterns, it provides dimensions that may be universally applicable to behaviour change. Therefore, if the design dimensions are considered during interventions that encourage a change in consumer behaviours, a change is expected to occur as a result. Considering this, the model proposed by Froehlich (2009) is used to guide the design of interventions used in this study. Further, Fang and Hsu (2010) extend these dimensions to include an emotionally engaged component, which suggests that influencing an emotional response for a given behaviour will result in a persuasive system that is more likely to lead to sustained behavioural change (Creed & Beale, 2005). In addition, Bishop (2005) explored the topic of motivating users to be more involved in online communities, finding that rewarding participants for their participation encouraged a maintained long-term behavioural change. These further elements are used to guide the design of the interventions used in this thesis.

2.4 Sustainable HCI

Sustainability is a significant topic in the field of human-computer interaction and is frequently used regarding energy consumption or sustainable food consumption (DiCalvo et al. 2010). Sustainable HCI is a subfield of the human-computer interaction community and was first discovered by Blevis (2007). Although other researchers had previously studied the role of technology and environmental sustainability (Jain and Wullert, 2002; Friedman et al., 2006), Blevis' work served as a catalyst to organize and formulate particular research agendas around environmental topics. Blevis (2007) discussed that sustainability should be the main focus of interaction design. Since then, sustainable HCI has become one of the fastest growing areas of research in the HCI and Ubicomp research communities. Blevis introduces both the potential of HCI contributing to prolonging the lifespan of computers and related products and thereby reducing the environmental impact related to the rapid obsolescence of these products and making people behave in more sustainable ways. Shortly after this was published, two directions were crystalized more clearly by the introduction of the terms, Sustainability in Design and Sustainability through Design (Blevis, 2007). Sustainability in Design focuses on the environmental impact of the products themselves,

whereas Sustainability through Design focuses on how HCI can support sustainable lifestyles and decision-making. However, depending on how the boundaries of Sustainable HCI are defined, it tends to focus on computers, information systems, and technology-driven approaches (Mankoff et al., 2007).

Tscheligi et al. (2007) and Reitberger et al. (2008) discussed that users can obtain feedback about the environmental impact of their actions by using persuasive technology. Brewer (2014) argued that sustainability has current issues to deal with. He suggested three ways to a better sustainability: (i) shift from creating only small-scale solutions to systems that are scalable to many users, because the problem in sustainability is vast in scale, (ii) shift from short-term solutions to 'sticky' solutions that will continue to have an impact over decades, and (iii) the sustainable HCI community must shift from limited focus on our community to a wide-ranging engagement and association with other research communities involved in sustainability research, such as psychology.

Food and ecological sustainability have gained more interest in HCI and often support local communities such as interactive technologies (Light et al., 2010) and farmers' markets (Odom, 2010). Several methods of alternative food practices support technologies to help local food production, sustainable food consumption, and sustainable land use. The current purposes in the domain of ecological sustainability focus on sustainable food purchasing practices such as providing consumers with local purchase information (Li et al., 2009), enhancing supply chain clarity (Bonnani et al., 2010), and assisting consumers during shopping (Kalnikaite et al., 2011). To design effective interactive systems, the user should participate during the design process to experience "anticipation for the technology's socio-cultural, health, and environmental impact" (Choi and Blevis, 2010, p.116).

Another food-related work focuses on supporting healthy eating (Grimes et al., 2008). Ecologically sustainable diets and healthy eating have several aspects in common, including encouragement of healthy options. However, there is a difference between sustainable food consumption and health-related food topics. The motivation for healthy eating is more likely to be immediately clear (for example, feeling better or losing weight). Reducing waste by reducing food consumption could lead to financial saving, either as a perceived or actual

benefit. Raising food prices led to 13% reduction of domestic food waste between 2006, 2007, and 2010 in UK households (WRAP, 2010). Quested and Parry (2011) indicated that about one-fifth of purchased foods are wasted. Thus, consumers could waste less food by changing their shopping patterns and being more careful of food handling practices rather than consuming less.

In this thesis, the target is for the household to build effective HCI interventions to achieve better food practices because 30% of food waste is generated from households (Ambler-Edwards et al., 2009). These interventions include smart fridges (Alolayan, 2014), smart kitchen appliances (Kirman et al., 2010), and smart kitchens (Olivier et al., 2009). These Ubicomp sensor-based technologies unfold new opportunities to support food practices and promote food waste reduction.

2.5 Chapter Summary

This chapter reviewed the literature pertinent to this study. These topics include food waste, behaviour resulting in food waste and food waste causes. This study of the literature indicates that little is known about the factors that influencing consumers behaviour that result in domestic food waste. The research presented in the following chapters aims to discover more about behaviour that leads to food waste and about how technology could support behavioural changes to reduce food waste.

This chapter also reviewed behavioural change models. Stern's value-belief-norm theory provides a framework for investigating the causes of consumer's behaviours leading to food waste and will be used during collecting data and data analysis as well.

Moreover, this chapter covered different types of context-aware and persuasive technology and engagement methods for intended behavior change process with focus on push information as an effective method to impact behaviour change. However, the literature lack the impact of persuasive technology on consumers' long-term behaviour change so as waste less food by targeting food before goes to waste.

In relation to related work, the history of existing interventions that reduced food waste were covered and how these interventions target food when it becomes waste. Finally, the role of sustainable HCI was covered and the recent interest from HCI community on how to build effective technologies to change behaviour and influence decision-making process.

The impact of VBN theory will continue in the next chapter, as it is part of the data collection and data analysis. This literature review shaped the structure of the methods identified later in chapter 3 that leads to answer the research questions of why consumers waste food and the How could persuasive technology help consumers change their behaviour so as to waste less food?

Chapter 3 Methodology

This chapter presents the thesis methodology that can be used to investigate and inform the design and evaluation of the persuasive context-aware technology presented in the following chapters. This technology aims to change behaviour and influence decision-making process to increase reflection, awareness, and participation in the domain of sustainability. The research approach that was adopted is presented, and the relationship of the methodology is explained with regard to its relevance to both previous and current research. The chapter revealed underlying gaps in the literature that present opportunities to explore and investigate. These were translated into two research questions. This chapter provides the foundation of the research methodology for investigating the research questions.

3.1 Research Approach

Research methods from different fields such as HCI, environmental, social psychology, and field studies were used in this work. The two most popular approaches in social science are positivism and interpretivist. Both of these approaches will be reviewed before justifying the approach chosen in this thesis.

Positivism belongs to epistemology, which is the philosophy of knowing and objects of nature. The responsibility of the researcher is restricted to data collection and analysis through objectives identified, and research findings are mostly recognizable and measurable. Positivism depends on quantifiable observations and statistical analysis. These definitions show that this approach would not be appropriate for this thesis because the aim is to investigate and study the influence of a given system on users by implementing qualitative methods. Moreover, the researcher is independent in positivism studies, which means that little interaction would occur with research participants (Crowther and Lancaster, 2012).

Interpretivism (interpretivist) research invites researchers to understand facts of the study, thus it integrates human interest. Interpretivism emphasises value and might apply several methods to reflect diverse parts of a given problem. The most popular primary data collection methods are interviews and observation. Interpretivist research generates primary data that has a high level of validity and low level of reliability. Interpretivist research depends on the participant's views of a given issue that is being investigated by the researcher. The researcher asks questions to the participants to determine the participants' thoughts and establish a clear meaning of the issue. The research can be developed over a long period of time (Creswell, 2009). It enables the researcher to understand why and how something happens in a given situation.

The aim of this thesis is to answer research questions RQ1, why consumers waste food, and RQ2, how could persuasive technology help consumers change their behaviour so as to waste less food. Thus, we investigate first why consumers throw food away in chapter 4, and then these causes will be used to build a future effective technology. Table 3-1 illustrates the research questions and the methods related to answer them.

Therefore, interpretivist research would be the most appropriate research approaches to guide the research design. Interviews and observations are used to gather data that is interpreted by the researcher with some quantitative data was used as well. Interpretivism is about understanding how and why people do what they do in a given context, rather than about predicting what will happen.

The VBN theory provided a framework for interpreting the data that was collected. The VBN theory (Stern, 2000) explains environmentally significant individual behavior and was found to be useful to study the influence of consumer decision-making behaviour related to food waste practices, thereby, encouraging behaviour change. The methods undertaken and the reason for choosing VBN will be covered in details later in section (3.4).

3.2 Study Validity

Study validity refers to the accuracy of study findings. Creswell (2009) explained that qualitative research should check the accuracy of the findings to ensure validity and reliability of data. Smith (1996) suggested using internal coherence and evidence presentation. Internal coherence means whether the argument presented is consistent and support by the data; evidence presentation shows the appropriate quotations from participants to allow readers to assess the analysis. Maxwell (2012) argues that qualitative research should address various threats to validity and present ways to reduce the threats. Informing hypothesis randomized sampling, assignment, and undertaking tests to determine variables that may be statistically significant can reduce threats. Specific threats should be highlighted and methods to address these threats should be discussed as part of the study design. He also added that researcher bias and reactivity are two major threats to validity. Maxwell (2012) argues that a researcher has less influence on participants' behaviours during observation studies. The research influence on participants is inevitable, and it is important to understand if the participant is influenced. The following describes several strategies that can be used in qualitative studies to increase accuracy of data (Maxwell, 2012):

- Intensive, long-term involvement: Collect data over a long period of time from participants.
- Rich data: Use long-term involvement and intensive interviews that provide enough details of a given situation.
- Respondent validation: Seek interpretation of research data and conclusions from participants (Lincoln & Guba, 2011).
- Searching for differences in evidence and negative situations: Report any differences in evidence and negative situations; then allow readers to evaluate and draw conclusions.
- Triangulation: Use different methods from variety of participants from different backgrounds and circumstances to reduce the risk of associations and systematic bias.
- Quasi-Statistics: Use implicit quantitative components to test and support findings from qualitative method (Becker, 1970).

- Comparison: This can be done through multisite studies to compare and test the findings from each study.

3.3 Recruitment and Selection of Participants

To be eligible for the studies undertaken in this thesis, participants needed to do food shopping, and own a fridge and smart mobile phones, with a focus on participants who are responsible for planning, shopping, and cooking practices. Households were recruited using a variety of methods such as emails, social network sites, university newsletters, and 'snowballing' through contact with participating households. Snowballing recruits future subjects from among their acquaintances (Goodman, 1961).

During the early recruitment stage, potential participants were contacted by email with the recruiting letter that clarified the purposes and aim of this study (Appendix A and D). Then, the chosen participants signed the consent form at the beginning of this study (Appendix B and F). The consent form explained how the data will be used and explained the right for participants to withdraw from this study. The sample size in each study was limited in accordance with practices outlined by Nielsen and Molich (1990). They argued that large samples of design evaluators could reduce the quality of outcomes and recommended a small group of about three to five design evaluators.

The quota requirements are based on the following elements:

- Household size
- Household composition (Couple – Family with children – Shared household)
- Gender and age
- Household composting activity
- Type of property
- Type of mobile phone
- Kitchen modalities (available Wi-Fi, power plugs, fridge light)

3.4 Study Design

There are total of three studies undertaken in this thesis using qualitative with mixed methods integrated. First, an investigation was performed of the causes influencing consumer decision-making process leading to domestic food waste by conducting individual interviews with in-home tours. Second, the data collected from the first method was used to build the early version (first prototype) of the persuasive context-aware technology. The first prototype was installed in one household and the study was continued for five weeks. During this time, participants were asked to use the system as they desired. At the end of the fifth week, a focus group was conducted with members of the household to gather data about whether the technology changed consumers' behaviour and had an impact on their decision-making process. Third, the researcher used collected data from the first prototype study to build an improved second prototype (EyeFridge) and install it in another five households for a period of five weeks. At the end of the fifth week, individual interviews were conducted at the end of the study to compare results with the first prototype study. The study design was reviewed and approved by Aberystwyth University ethics committee. The following sections explain each study in more details. Also, refer to Table 3-1 for a summary of research methods, literature gaps and how they answer research questions.

These strategies were applied in this study and integrated into individual research activities to ensure validity of this thesis. For example, the data collected from the first prototype provides rich information that was compared with outcomes from the second prototype to improve the design of the technology and to change consumer's behaviour and influence their decision-making process in domestic settings. Throughout the three studies in this thesis, qualitative methods were used with mixed methods integrated under the scope of VBN theory to examine if participants engaged or did not engage with the technology.

3.4.1 Study 1: Identify Key Factors Influencing Consumer Decision-making Leading to Food Waste

To build an effective persuasive context-aware technology that change consumers' behaviour in the sustainability area, first we need to identify causes that influence consumer decision-

making leading to food waste. Engaging seven participants in six different households conducted individual interviews with in-home tours over a five-week period (Pierce and Paulos, 2011; Strengers, 2011). Participants were asked semi-structured questions to explore attitudes and behaviours undertaken by households relating to grocery shopping, planning, cooking, food storage practices, and food waste management (Appendix C). The interviews were recoded and transcribed. The goal here is to provide extensive insights into participants' behaviours to identify food waste causes and determine how we can use this data to build a persuasive context-aware technology that change consumers' behaviour. The outcomes provided key themes that translated into causes of domestic food waste, and therefore answered research question RQ1. This should fill the gap in the literature of why consumers waste food in households. Many technologies target food waste reduction, but none target the causes or factors resulting in food waste.

After conducting interviews, the researcher asked participants for permission to conduct an in-home tour and to show the researcher current food waste in the household, and where and how they store food. The researcher also took pictures during the tour. Refer to Section 4.2 for more details about this the methods undertaken in this study. Only two of the seven participants did not agree to the home tour. Photos taken will confirm the findings from individual interviews.

3.4.1.1 Data Analysis

The qualitative data collected through the study has informed the data analysis method. Coding collected data was adapted to analyse the raw data. This coding method allowed the researcher to obtain the value from phrases, sentences, or entire paragraphs to improve the understanding of the relations between thematic areas. A code is a character that is collected from a series of letters or numbers (Robson, 2002). Coding is a procedure that allocates entities of value to the descriptive or inferential information to analytically categorize the data collected (Miles and Huberman, 1994). During the analysis, the researcher transcribed and transferred raw qualitative data into a computer application. The data were analysed and coded manually rather than employing automated techniques. The manual technique gives the researcher the feel of data and become recognisable with the transcript within constant

reading and inputting, which helped the researcher to be able to code confidently (Robson, 2002). The specific content and phenomenon that allocated with a similar theme were categorized with codes. The coded themes were presented into maps to support evaluating and ordering of the raw data. The facts that had similar characteristics were gathered to build theory (Miles and Huberman, 1994).

The interview data was transcribed and analysed by the researcher. Then the data was organized and reorganized in terms of categories by adopting coding and clustering techniques. Data and code were then captured in Dedoose Analyser, an open source qualitative research tool. The data was analysed further and allocated with codes. Finally, inductive thematic analysis (Braun and Clarke 2006) was performed to offer an understanding of the relations regarding environmental awareness and human behaviour as well as the opportunities and obstacles faced when designing an effective persuasive context-aware technology. The outcomes of the interviews provided key themes, which translated into factors leading to domestic food waste.

After collecting the in-tour home photos, the researcher went through the images to facilitate reflection and discussion of the interviews. Visual ethnographic techniques (Pink, 2007) were applied to cross-reference the interview outcomes with associated photos to corroborate what was said. Visual ethnographic involves approach that engages with audio or visual media and methods throughout its process of research, analytics and representation. This, in conjunction with data collected from interviews, will help in identifying household shopping practices.

3.4.2 Study 2: First prototype

A new persuasive context-aware technology was designed and built to collect meaningful data of participants' everyday interactions with the food storage space. This prototype supports users' awareness and reflection, and to influence their decision-making process in the sustainability area. First, using a mobile phone attached inside the fridge door to take pictures of the fridge contents every time the fridge door is opened. The captured photos are uploaded to a dedicated website where users can access the latest eight photos. The first

prototype was installed in one household (total of five participants) over five consecutive weeks.

The researcher gave participants a consent form to sign and agree upon beginning participation in the study (Appendix B). In addition, participants were given a manual that includes username and password to access the website where they can access the photos. The researcher described in detail to participants how to use the system and explained that the participants could use the prototype as they wanted. Participants were contacted twice via email through the study period to check if everything was going well. At the end of the fifth week, the researcher visited the participants again in their households to terminate the study. A focus group was conducted with members of the household (five participants in total). They were asked many open-ended questions relating to effectiveness of this prototype, and whether they have used it when planning or while doing grocery shopping, or they just relied on their memory to retrieve available food in the fridge (Appendix H). Refer to Section 5.2.4 for more details about this study.

During the field deployment, a number of strategies were used to ensure that the sensing was functioning properly. First, the mobile phone would be plugged into the charger constantly to make sure the battery would not die during the deployment. Second, the researcher could view a secure website of each household's current fridge content.

3.4.2.1 Data Analysis

The focus group data was transcribed and analysed. Qualitative data was analysed using Dedoose[1], a web application that can manage and analyse data. Also, this app allowed the researcher to code, organize, and collect transcripts and related data. Transcripts were examined thoroughly to identify and note themes; themes were given temporary titles and grouped with preliminary interpretations. Thematical analysis (Creswell, 2009; Given, 2008) was applied to the focus group interviews to derive emergent underlying themes.

[1] http://www.dedoose.com

After collecting the images of fridge content, the researcher went through the images with the participants during the focus group session to facilitate reflection and discussion. Visual ethnographic techniques (Pink, 2007) were applied to better understand the movement of food observed taken from fridge content. Later, the interview outcomes were cross-referenced with associated photos to corroborate what was said.

In addition, daily visits to the prototype website were tracked and analysed using Google Analytics. This enabled the researcher to see the number of times participants visited and accessed the fridge content online and the time spent per visit. Moreover, mobile versus non-mobile browser visits were tracked to analyse if participants used it on the go.

3.4.3 Study 3: FridgeReminder – Design for Long-Term Behaviour Change

The outcome from the first prototype was used to design an improved second prototype. The aim here is to investigate if the second prototype has an impact on behaviour change and influence decision-making process. The second prototype was installed in another five households (total of five participants) over a period of five weeks.

At the end of the fifth week, the researcher visited the participants again in their households to terminate the study. Individual interviews were conducted with participants, and they were asked many open-ended questions relating to the effectiveness of this prototype, their thoughts about notifications and reminders, and if they used it when planning or while doing grocery shopping or they just relied on their memory to retrieve available food in the fridge. Also, participants were asked whether the added notifications and reminders had an impact on participation and reflection as well as motivated the participants to improve their decision-making (Appendix J). Refer to Section 6.5.2 for more details about research methods undertaken for this study.

The interviews were recoded and transcribed. This method helped to understand and answer research question RQ2 and monitor experience of the data created by participants from their everyday lives. Also, it helped to understand how and why the persuasive context-aware technology could be affected. It is important to use the qualitative method to analyse

collected data and provide details that cannot be determined by the quantitative method, which uses numbers. This seeks to address all the identified causes resulting from the first study.

During the field deployment, a number of strategies were used to ensure that the sensing was functioning properly. First, the mobile phone would be plugged into the charger all the time to make sure the battery would not die during the deployment. Second, the researcher could view a secure website of each household's current fridge contents and update the recipes based on the content as well as send reminders to the participant's phone when items were running out or low.

3.4.3.1 Data Analysis

Interviews were transcribed and analysed using a web application called Dedoose. Inductive thematic analysis (Creswell, 2009; Given, 2008) was applied to analyse the interview data.

At the end of the study, the researcher went through the captured photos of the fridge content with participants to facilitate reflection and discussion. Visual ethnographic techniques (Pink, 2007) were applied to better understand the movement of food observed taken from fridge content. Later, the interview outcomes were cross-referenced with associated photos to corroborate what was said. Web traffic was analysed to determine the number of clicks and visits each participant made. This helps to understand if engagement increased compared with that of the first prototype.

Participants were told to reply to notifications with the word 'OK' if they followed up with a decision or action. For example, a participant might get a notification on the way home from work of an item running out, and then pop into the shop to buy the item needed. Participants would reply to the notification message (whatsapp messages) with the word 'OK'. These methods were illustrated in Section 6.4.1.3 for more details. This would enable measurement of the effectiveness of notification on consumer decision-making. The only limitation with this measurement is that participants could forget to reply to notifications and reminders when they made an action after receiving a notification. Ethical Issues

This experiment gathered data from participant's everyday interactions in the home environment, in this case with the fridge, and from information recorded during interviews. Participants access the fridge content photos by using login details (username and password) assigned to each participant. Consent Forms (Appendix B and D), which explained that the information would not be used for any purpose other than this study, were provided and signed by participants. The researcher asked participants for their permission to use fridge content photos at published papers and conferences. Also, it was explained to participants that it is the researcher's responsibility to protect their privacy, and they were not required to answer any questions they felt uncomfortable to answer.

Research Question	**Literature gap**	**Methods**		**Data Analysis**
Why consumers waste food?	Causes behind domestic food waste that influence decision-making process.	Interviews In-home tour		Thematic analysis Visual ethnographic techniques
How could persuasive technology help consumers change their behaviour so as to waste less food?	Many technologies target food waste reduction when the food is already wasted, but none target the causes or factors leads to food waste. Many technologies failed to engage the consumers in a long-term behaviour change.	First prototype	Focus group Visual ethnographic Web traffic	Thematic analysis Visual ethnographic techniques Web analysis
		Second prototype	Interviews Visual ethnographic Web traffic Review and response to notifications	Thematic analysis Visual ethnographic techniques Web analysis See function on whatsapp and reply with word 'OK' if an action is made.

Table 3-1. Research questions and methods to answer them

3.5 Chapter Summary

The chapter presents and describes the thesis methodology and introduces an approach that combined quantitative methods with mixed methods based on VBN theory. Some of these methods are quantitative, but their findings were limited due to the small number of participants studied. However, they provided a good indication of interaction.

The methodology structured in three studies to answer research questions. The first study plans to conduct using individual interviews and in-home tours under the scope of VBN theory as part of data collection and analysis. The findings from this study should identify the causes of consumers' food waste.

The second study combined focus group, visual ethnographic and web traffic also under the scope of VBN theory. Results should define whether this prototype of context-aware persuasive technology has an impact on behaviour change and future design improvements.

The final study integrated individual interviews with ethnographic and web traffic using the VBN theory as a lens to analysis the data collected. The findings from the previous study (first prototype study) should draw the design requirements of future context-aware persuasive technology that influences decision-making process and long-term behaviour change.

Chapter 4 Factors Influencing Consumer Decision-Making Leading to Food Waste

Many researchers argued that domestic food waste is influenced by consumer behaviours. Interventions aimed at directly changing behaviour have met with varied success. This is due to the challenging nature of changing behaviour; maintaining changed behaviour in the long term is even more challenging. However, this thesis does not aim to change consumer behaviour directly. The aim is to encourage behaviour change by identifying factors influencing consumer decision-making leading to food waste, and providing information that will support better decisions. Once these factors are identified, they can be targeted by interventions, thus promoting more sustainable domestic food practices.

The literature review indicated that most interventions that target domestic food waste pursue the goal of reducing food waste in several ways. Some interventions encourage users to consume food items that otherwise might be wasted because of a lack of knowledge of how to consume them (Bucci et al., 2010; Gartland and Piasek, 2009; Lim et al., 2014). Other interventions aim to increase user food waste awareness (Thieme et al., 2012). However, none of these interventions target behavioural factors that influence consumer decision-making resulting in domestic food waste. Also, the literature indicates that the majority of domestic food waste is produced during everyday food practices (Godfray et al., 2010; Schlegelmilch, Bohlen, & Diamantopoulos, 1996; Young et al., 2010; Darlington & Rahimifard, 2006; Vermeir & Verbeke, 2006). These behaviours leading to food waste are results of consumer decision-making during food practices. The primary question addressed by this thesis is to identify these factors influencing consumer decision-making leading to food waste and is subsequently guided by research question RQ1.

This chapter proposes qualitative and in-home tour studies to identify key factors influencing consumer decision-making behaviours that lead to domestic food waste. This study will employ value-belief-norm theory (Stern, 2000) and its four causal variables as a lens to understand and identify relevant factors.

4.1 Understanding Consumer Decision-Making Behaviour through the Lens of VBN Theory

To effectively influence individual food waste behaviour, its underlying determinants need to be better understood first. Furthermore, it may seem interesting to research whether people perceive food waste as an environmentally significant behaviour, thus, whether they recognise its environmental consequences. One theory aiming to explain pro-environmental behaviour is Stern's (2000) Value-Belief-Norm (VBN) theory of environmentalism.

The VBN theory has not yet been applied in the context of domestic food waste behaviour. However, This theory will help answering RQ1 of why consumers waste food and also answering RQ2 if the technology encouraged behaviour change and decision-making process by using VBN four variables as a data structure and analysis. The VBN theory was explained earlier in section (2.3.1) and how this theory used in this thesis in section (3.4).

This theory categorized these relevant variables into four major types and may provide a framework for explaining consumer decision-making behaviour leading to food waste:

- Attitudinal factors include an individual's values, beliefs, and attitudes, such as individual's environmentally behaviours.
- Contextual forces include advertising, interpersonal influences, the ease or difficulty of particular actions, community, social, and political expectations. Examples are buying three for two or unexpected events.
- Personal capabilities include knowledge, available time and money, social status, and power such as expiry date.

- Habits or routines are actions established from an individual's everyday practices such as writing a shopping list or checking the fridge content before shopping.

4.2 Data Collection and Analysis

Individual interviews with in-home tours were conducted by engaging seven participants in six different households as discussed earlier in section 3.4.1 (Pierce and Paulos, 2011; Strengers, 2011). Participants were asked semi-structured questions to explore attitudes and behaviours relating to planning, grocery shopping, cooking, food storage practices, and food waste management (Appendix C). Participants were recruited from a university newsletter and went through a recruitment process before they were chosen. Only young adults responded to this kind of study because they produce the most food waste but keen to raise their sustainable awareness (WRAP, 2012). However, this might affect the diversity of participants chosen and validity of the findings. Future work should cover participants from different age groups.

Interviews took 30 minutes on average. Thematical analysis (Creswell, 2009; Given, 2008) was applied to the interviews to develop emergent underlying themes under the VBN theory lens. The outcomes of the interviews provided key themes, assess participants' views of the four VBN theory variables, which translated into factors leading to domestic food waste.

After conducting interviews, the researcher asked each participant's permission to perform an in-home tour and show the researcher current food waste in the household, and where and how they store food. The researcher also took pictures during the tour. Only two participants did not agree to the home tour out of the seven participants. Photos taken will confirm the findings from individual interviews.

	Age	Gender	Occupation	Social situation	Shopping habits	Food waste production in the household
P1	31	Male	Hotel manager	Lives with 4 other housemates	Every two days	1L bin a week
P2	35	Male	PhD student	Lives with 2 other housemates	Big shop weekly then top up every three days	0.5 bin a week
P3	20	Female	Undergraduate student	Lives with 4 other housemates	Every week	1 bin a week
P4	21	Male	Undergraduate student	Lives with 4 other housemates	Twice a week loads of free vegetables from the market	5L bin a week
P5	20	Male	Undergraduate student	Lives with 5 other housemates	Big shop weekly then top up every three days	1L bin a week
P6	25	Female	Sales assistant	Lives with 4 other housemates	One large shop a week	0.5L bin a week
P7	35	Male	Self-employed	Lives with 2 other housemates	Every week	0.5L bin a week

Table 4-1. Summary table of study participants

4.3 Findings

The findings here explained participants' perspective of everyday domestic food practices in the context of sustainability. The findings are organized around the broad themes of VBN theory four variables and specific practices around food waste. The data highlights that while almost all of our participants wanted to engage in sustainable food practice in some way as indicated earlier, people often experience a gap between what they want to and what they actually do in everyday life, as discussed earlier in the literature (Vermeir and Vebeke, 2006).

The following covers the findings under the four variable of VBN theory during everyday food practices.

4.3.1 Attitudinal Factors

Attitudinal factors include an individual's values, beliefs, and attitudes. Such are individual's environmentally behaviours. The findings indicated that all of the participants were concerned about their environmental behaviour and food waste, and they do not like throwing out food. They claim that they feel guilty when they throw food away:

Food waste does bother me. Sometimes I feel guilty then I start asking other people if they would like to have it (P1).

One of the participants expressed his attitude toward reducing food waste as he undertook a challenge he set himself last summer. He cycled from London to Berlin completely penniless, and he had to live off food waste and food donated by strangers he met along the way. He said:

On this journey I learnt a lot about the amount of food being wasted, how edible most of it actually is (even food from dumpsters behind street markets), and the kind of action people are taking to reduce it. One example is a huge group throughout Germany that you've probably heard of called The Foodsharing Network. I actually met with the founder of the network while passing through Braunschweig in north west (ish) Germany, and he showed me all the work he has been doing to get leftover food from bakeries, supermarkets, farmers markets etc. and to take it to a single place where students can go and take whatever they want for free (P4).

Also, P1 shows his environmentally attitude towards leftover by feeding it to the animals. He explained:

I always give leftover or unwanted food to the birds and sometimes to the cat that pop over into our garden every while and then.

Whereas P3 gave leftover and unwanted food to his flatmates:

Any leftover I have I offer it to my flatmates.

These findings shows positive attitudes, values and beliefs of participants' towards food waste and most of them felt guilty about throwing food away. This indicated that attitudinal factors are not a major factor towards decision-making leading to food waste. This is because all participants have an interest and good intentions towards sustainable lifestyle and food waste reduction.

4.3.2 Contextual Forces

Contextual forces include advertising, interpersonal influences, the ease or difficulty of particular actions, community, social, and political expectations, such as storage space. Storage space played an important role in the amount of food waste. The more storage space available, the easier it was to allocate food in the fridge or shelves. P1 had a limited fridge space. He said their fridge was small for five people sharing the house. Space for keeping food in the fridge plays an important role in how frequent the shopping must be done, as illustrated by P1:

I live in a shared house. I only buy limited items because we don't have enough space in the fridge.

Bulk purchasing was also one of *contextual forces* of expired food waste, such as buying tomatoes in bulk and not using them all when cooking. In addition, participants explained that overbuying using special offers, such as buy three for two, were less expensive, but also a *contextual force* often resulted in food being thrown away:

Normally I don't buy more than I intended; I just buy what I need. Sometimes I do buy more if there is something I really like and it is on special offer. This additional item is often thrown away (P6).

However, some participants explained that changing circumstances force them from consuming the food they planned to cook or eat:

Sometimes I have to stay late at work. I don't have energy when I get back home to cook what I have planned. This happened so many times, leading to expire food waste (P7).

Cooking practice was a *contextual force* for P4. He cooked every day because he got free vegetables from the market he works for every Saturday:

I got sometimes 20 onions and stuff like that. I don't consume the whole amount—I probably chopped half of them. I try to make meals with onions to avoid food waste.

He also added:

Most of the stuff slightly went waste, especially the vegetables (fresh food) I got from the market for free. I normally when I get back from the market I get fresh stuff and replace with the stuff I get. I probably waste less if I am not working at the market.

4.3.3 Personal Capabilities

Personal capabilities include knowledge, available time and money, social status, and power such as retrieving available items and its location. Some participants specified that they would forget the available items and their locations, specifically, if placed or pushed back in the fridge or cupboard. Participants explained that these items expired more frequently than others and they would not find them until the storage space was organized. These findings show that consumers need to be informed about the available food items and their locations through adopting methods or building effective interventions to better retrieve available food and location. This could highlight the benefit of having an organized and transparent approach, which is associated with food waste reduction.

Remembering and retrieving items available in the household is a huge challenge for participants when it comes to planning and shopping. Some participants are often uncertain about available food in the household; this leads to them purchasing food they already have in the household:

I occasionally buy items that I thought I don't have in the fridge (P7).

These findings show that consumers need improved methods and effective interventions to retrieve and increase their awareness of food items available in storage spaces and their locations. This will result in making better choices during food shopping practices, which will reduce food waste.

Another personal capability is participant's busy lifestyle that prevented them from examine the fridge prior food shopping:

When I do shopping I'm just like in a rush to get it done I don't even check what's in the fridge (P3).

Also, their busy lifestyles prevent them from cooking. They frequently heat up frozen and canned food for cooking: "*I buy loads of frozen stuff*" (P3). While others only cooked at the weekend when they had more time:

When I think of what I can cook and what I need to do this, and then plan my meals based on the ingredients I have. And I plan my meals for the forthcoming week as well. I consume what I cook on the same day; sometimes I eat the leftover the next day (P6).

Moreover, many participants explained how they get inspired from recipes available on the Internet in order to consume unwanted ingredients. They stated that they search for recipes on the Internet whenever they have time and feel creative. They often search for new recipes when they have unwanted food they do not know how to consume. They type these foods as search terms to look for recipe suggestions. P1 added that he tried to think about creative recipes to cook to use unwanted and leftover ingredients before they expire:

I don't eat much salad and vegetables but I can make a juice out of it. Sometimes I go online for creative ideas.

Another personal capability to avoid food waste was to purchase food with the longest expiry date. This shows participant's knowledge of the products and the appropriate time to consume it. For instance, most of the participants explained that they check the expiry date before purchasing items, and they always go for the item on the back of the shelf because it has the longest expiry date:

I usually buy the one that has the longest expire date, usually at the back of the shelf (P5).

Moreover, participant's knowledge of buying reduced food can save some money while helping reduce food waste. P4 explained how he buys reduced items and freezes them to extend the shelf life:

I do buy reduced items and then freeze because you know the other stuff is more expensive.

This show how participants are willing to change behaviour to more sustainable behaviour by using food creatively and in more different methods before it goes to waste.

Also, participants' knowledge of measuring food portions leads to occasionally cook larger meals than they would consume in a single sitting. P5 explained his food waste comes from cooking too much rice and discarding the leftover because it lost its value and taste over time. It was difficult for him to determine the correct amount he needed:

I cook so much rice and I don't like to eat it the next day. I can't really measure how much exactly I am going to eat. My food waste comes from rice.

4.3.4 Habits or Routines

Habits or routines are actions established from an individual's everyday practices such as the approach of storing food. Food brought into the household is first stored in storage spaces such as fridge, cupboard, and pantry before it is consumed later. Storing food is the most important practice that influences consumer behaviour leading to food waste. During the investigation, participants talked in detail of how they stock their food in the household. For example, P1 had a categorization approach of how and where he stored his food. P1 indicated that throwing away food was not common in their household, because of the categorization approach of their storage system and because all household members proactively took part in making themselves aware of the available food items and their locations. There are some comments regarding the low visibility of food items within the refrigerator, particularly the food that was pushed back in the fridge or shelves. Participants' responses showed that employing the categorization approach helped them to memorize available food in the household. However, other participants did not follow the categorization approach and placed items in food storage spaces randomly. During the in-home tour, P1 provided an example of a household that implemented the systematic and categorization approach (Figure 4-1). P1

explained that wasted expired food was not common in their household. However, other participants did not implement the categorization approach.

Figure 4-1. Storage management in P1 household

Participants had habits and routines to help in retrieving food supply items and also their locations. These strategies include looking at the fridge or any other places where they store food and making a list before going grocery shopping. Three of our participants revealed that they made a list of the food they needed to buy:

I do make a shopping list. I usually check what is inside the fridge and cupboard before going food shopping (P2).

However, some other participants rely on their memory. They did little or no preparation prior to food shopping:

I don't make a list. I just depend on memory (P4).

The list was not helpful for everyone, including P1, for whom shopping was something he did almost every day, and he knows what is in his fridge:

I don't make [a] shopping list. I know exactly what I have in the fridge. I'm very selective with what I drink or eat.

However, the relation of the list to what is bought is different. Moreover, making a list was important regarding efficiency. Yet, half of the participants reported buying additional items than what was on the list:

Usually I stick to my list but sometimes I don't, not very frequently maybe every while and then I buy additional items that look tasty (P2).

Some participants explained that they make a list based on the planned meals they intend to cook for the upcoming week to avoid food waste:

Based on what I'm going to cook, basically how I do shopping based on my work schedule; if I'm working on the weekdays then I will focus to cook on three days out of five days because if you cook for two days you will have food that will last for three to four days (P1).

Some participant's routine was to cook large meals regularly and divided them into several meals by wrapping or repacking them and then placing them in the fridge or freezer to consume in several days:

I cook a lot! I cook in the morning four to five meals per day but I eat three meals at school and the remaining at home. I repacked and placed in the fridge (P5).

From these findings shoppers could be categorized as 'organized shopper' and 'unorganized shopper'.

- Organized shopper: consumers who plan their shopping practice by creating a shopping list based on missing, wanted items, or planned meals. When creating the shopping list, consumers check food storage spaces such as fridge, cupboard, or pantry.
- Unorganized shopper: consumers who do not plan their shopping practice in advance and rarely examine their food storage spaces before shopping; thus, they end up buying multiple items they already have in the household. These consumers often buy the same items every shopping trip.

Participants shopping routines was a large shop once a week, with some 'top up' shopping trips to buy fresh foods, such as vegetables and fruits. Some participants explained that they shop from their favourite giant supermarket chains, while other participants stated they also

shop fresh food from farmers markets. Participants who buy from farmers markets explained how this type of fresh food expired quickly before they were able to eat all the food.

4.4 Discussion

The findings from the qualitative study were used to identify factors influencing consumer decision-making leading to food waste using the VBN theory lens. Attitudinal factors had a positive impact on consumers' behaviour since they show interest on the study and on environmental behaviour. None of our participants liked to throw food away, as they feel guilty whenever they waste food, and they all reported having good intentions, as explained by P1 in the previous section (4.3). However, these good intentions did not always transform into actions. Although our participants disliked wasting food, all had some events when they had to throw away food. Participants also engaged in positive strategies to try to avoid waste such as creating a shopping list, freezing food to extend its durability, being creative with recipes, and feeding leftover to flatmates, animals, and birds, as explained by P1 and P3. Throwing food away is something unintended and unplanned by consumers, and there is no simple explanation why consumers waste food. Blake (1999) stated that food waste is an outcome of practices that are extremely embedded in daily social, cultural, and practical contexts that produce challenging concerns.

The clearest theme outlined from the data analysis is that most domestic food waste produced from unintended consumer behaviours occurred during storing and purchasing practices. This is due to *contextual forces*, *personal capabilities* and *habits or routines*. Such behaviours occurred primarily because of methods of grocery shopping and storing of food. If real-time information of available food in the household is available during grocery shopping, consumers are less likely to stockpile food they already have in the household, thus establishing a new habit or routine of checking the fridge prior shopping and make a shopping list. Providing real-time information when planning or shopping practices would likely reduce food waste related to such behaviours. These findings supported the findings reported in the literature show that techniques to reduce food waste such as writing shopping lists and planning meals may help in food waste reduction and encourage better shopping

practices (Schnider, 2008). Therefore, future interventions that offer consumers real-time information about available food in the household storage space during food shopping practices could offer effective opportunities for future research. This will be investigated in Chapters 5 and 6.

Furthermore, consumers' habits of categorized storage method will help in reducing food waste with fresh food, such as milk. Sometimes these items are pushed back in the fridge and are forgotten until they expire. Therefore, this habit of categorized storing could support individuals to consume available food before it expires. An example is the use of a color-coding scheme within a household's fridge (Far-Wharton et al., 2012).

Moreover, *contextual forces* such as marketing and advertising that promote savings through bulk purchases influence consumer decision-making during food shopping (Baumeister, 2002; Ene, 2008). Examining this behaviour through VBN theory and the associated four variables, Stern (2000) claims that marketing and financial savings are *contextual forces* that can influence consumers' decision-making.

Food, such as onions and tomatoes, is often sold in bulk. Therefore, there is a need to increase consumers' *personal capabilities* of product knowledge such expiry date and improve creative food consumption before it goes to waste. This highlights opportunities for future research to investigate how to increase consumers' food knowledge and its edibility to reduce food waste.

Moreover, some participants' *personal capabilities* lead to cook large portions of food due to difficulty in measuring the correct portion of the food that will be consumed in a single sitting, such as pasta and rice. Occasionally, *contextual forces* such as unplanned events would lose consumer desire to consume the leftover food after one or two sittings (Schneider, 2008).

4.4.1 Factors influencing decision-making leading to food waste

The findings indicate that two major factors and three minor factors influence consumer decision-making, leading to domestic food waste using the VBN theory. The factors are

generated from *contextual forces*, *personal capabilities* and *habits or routines* and does not cover attitudinal factors since the participants had a positive environmentally behaviour.

4.4.1.1 Major Factors

Major refers to a significant contribution to behavioural intent; therefore, a great amount of expired wastage of food is produced. The two major factors are the following:

- **Remembering available food:**

The findings indicate that the major factor influencing consumer decision-making leading to food waste is remembering available food in the household. Consumers' *personal capabilities* of food supply knowledge when planning and food shopping lead to buy items that already are available in the household. This involves how consumers store their food, as well as consumers who do not plan their shopping in advance, such as creating shopping lists.

- **Remembering location of available food:**

Consumers' *personal capabilities* of memorizing the locations of items in the household, could lead to food waste. This is due to some items are pushed back in the fridge for limited visibility. The ability of consumers to locate desired foods could be evaluated by investigating the household routine. This consideration refers to the need for consumers to have real-time information that offers help with food location during planning or shopping practices or provides a routine categorised method of organizing items in the storage spaces.

4.4.1.2 Minor Factors

In addition, this study identifies three minor factors. 'Minor' refers to less important impacts on consumer behaviour, often due to *contextual forces*. Therefore, little amount of food waste is produced. These factors are:

- **Measuring correctly:**

Consumers face difficulty measuring the correct amount of food they are willing to consume, such as porridge, pasta, and rice. This can be studied through consumers' *personal capabilitie*s such as knowledge and skill to judge the appropriate amount to be consumed.

- **Unconsumed ingredients and leftovers:**

Consumers sometimes cooked a great amount of food with intention to consume it on different occasions. However, sometimes the consumer lost the desire to consume unwanted ingredients and leftovers. This could be due to the food losing its taste and value. This could be examined through *contextual forces*, with focus on the leftover food value.

- **Changing circumstances:**

Participants explained how their busy lifestyles could lead to unconsumed food that was purchased. Due to their busy schedules, sometimes they do not have the energy to cook with available ingredients for days; this leads to them not consuming that food, and it results in expired food. For example, the consumer planned to cook dinner from ingredients purchased but had to stay late at work. Therefore, this could be examined though *contextual forces*.

4.5 Chapter Summary

This chapter examined and identified the factors influencing consumer decision-making resulting in domestic food waste using the VBN theory lens. Employing the VBN's as a framework for conducting this study, which in turn answered the research question RQ1, identified two major factors and three minor factors. Factors identified resulting in food waste were influenced under *contextual forces*, *personal capabilities* and *habits or routines* and does not cover attitudinal factors since the participants had a positive environmentally behaviour. Employing the four causal variables identified by Stern (2000) helped to understand consumer decision-making leading to food waste, therefore, understanding these factors could promote more sustainable practices. Consumers explained their interest toward reducing food waste; however, *contextual forces*, *personal capabilities* and *habits or routines* could prevent them from reaching that goal. As explained before, attitudes and good intentions do not always translate into actions (Vermeir and Verbeke, 2006).

Understanding these factors provides opportunities for future research to target these factors and to reduce their influence on behaviours. Opportunities include technologies that provide real-time information of available food in the household storage spaces when planning or food shopping to change consumer's behaviour by breaking bad *habits or routines* and improve *personal capabilities*.

Chapter 5 First Prototype

In the previous chapter (Chapter 4), research question one has been addressed by investigating why consumers throw food away. Then build a future effective technology that targets these causes. This chapter presents the design and investigation of the first prototype, a context-aware persuasive technology that aim to change users' behaviour and influence their process of decision-making. This prototype addresses context awareness by means of sensor data (images) captured within the fridge. It forms a straightforward application of persuasive context-aware computing that change behaviour and influence decision-making process, in which the decisions in question relate to food planning and purchase. This technology addresses only one factor identified previously in Chapter 4, which is remembering available food. Moreover, the chapter discusses the design and build of the technology, the method of capturing data, and the type of data collected. This technology senses and collects data in the home environment and then presents it to the end-users through a web user interface. Interaction design for the context-aware interface is presented as well as the way in which individuals could use this system in practice. The interface helps users to access and explore the captured data to retrieve past interactions in domestic settings. This could encourage behaviour change and influence decision-making process related to food practices, and ultimately promote sustainable lifestyle. Investigation is carried out using qualitative methods integrated with mixed methods thrown in under the scope of VBN theory four variables*: attitudinal factors, contextual forces, personal capabilities* and *habits or routines*.

5.1 Context-Aware and Decision Support in Home Environment

Context-aware computing refers to systems that sense the location, collect data of nearby people and objects, and record any changes over a period of time (Schilit & Theimer, 1994).

The term is also referred to as a system that uses the context to offer significant information and services to users. To make effective decisions, users need to have the right information at the right time. The aim here is to integrate context-aware with decision support by detecting sensing users' contextual data automatically from sensors in the home environment. Then, this data is employed to offer relevant information and services to the user. This system will improve reflection and awareness, and it will support decision activities around food practices, which is the target area of this thesis. The system also could promote a sustainable lifestyle in domestic settings.

Simon (1960) states that the decision-making process involves three main stages: intelligence, design, and choice. In the intelligence stage, the decision-maker classifies a problem situation as the decision-maker's context data comes in as motivations to be determined, which is a gap between the goal and present state. In the design stage, suggestions are offered to lessen the identified gap through the problem situation. In the choice stage, the decision-maker makes a decision from the suggestions.

The context-aware decision-making process (Figure 5-1) includes context-aware models in the decision-making process (Kown, 2006). This could be through automatically identifying the decision-makers' context during the intelligence stage, and then offering suggestions and choosing one of these suggestions to make a decision could involve gathering previous data in the design and choice stages. The main ability of context-aware computing is context-awareness. Context-aware computing will sense context such as time, motions, date, and photos automatically and transparently provide that information to the decision-maker.

A context-aware decision support system contains two main integrated stages. The first involves how to sense, capture, and collect meaningful raw data that could be turned into visual data to retrieve when needed. The second focuses on how to design and build the user interface to access collected data visually. This interface should allow users to search and access data effortlessly and supply support for decision activities. Also, this interface provides real-time information to support users by memorizing past events related to food practices. This system can be attached in any food storage space (for example, fridge, cupboards, or pantry).

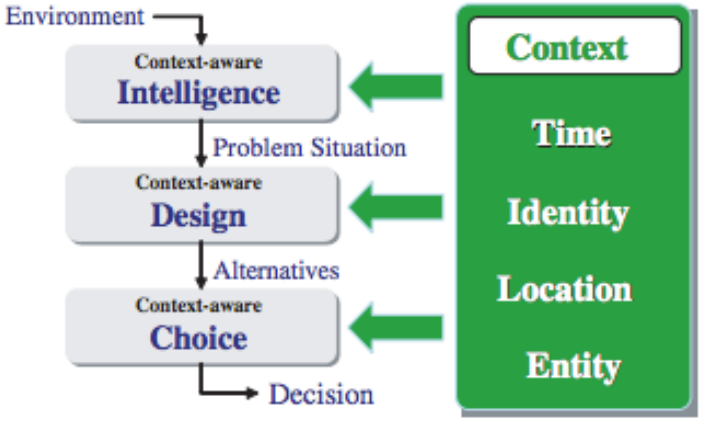

Figure 5-1. Context-aware decision-making process (Kown, 2006)

Several methods and tools for retrieving past events can inform the design of context-aware computing. These include the use of visual images (Conway, 2009), electronic emails (Sellen & Whittaker, 2010), SMS, and phone calls (Bisht et al., 2007) as reminders.

The collection of digital data such as photos could support retrieving past events to inform decision-making related to food practices. In this study, for example, the data could support the retrieval of one photo by providing contextual information about it, such as content of fridge, and date and time the picture was taken.

5.2 First Prototype Design

The first prototype aims to answer the following questions:

- What data should be captured?
- Why does data need to be captured?
- How should this data be captured?
- How this data change behaviour?

First, the prototype was developed, and then the user interface was designed and built. Finally, the system was installed in one household over a period of five weeks to investigate the impact of this data and the technology on participants' behaviour change and decision-making process.

In this prototype, the concept is to install a Samsung smart phone (capture device) in the home environment (in this case, inside the fridge door). Every time the fridge door is open, the accelerometer senses the movement and triggers the built-in camera to take a photo of the fridge contents). Photos are uploaded to a dedicated website where users can access and browse the photos (visual data) to inform their decision-making related to food practices.

5.2.1 Sensing and Capturing Tools

The aim here is to understand the type of data and metadata that the prototype should capture and the way it should be captured. Additionally, a description is provided of the device that the prototype uses to collect the proposed data, and the reasons for choosing this device are discussed.

A Samsung Fame Galaxy smart phone was used in this prototype to capture two different types of data: motions and photos. This phone was used because it is cheaper than other devices such as a camera and accelerometer or Raspberry Pi. Also, the smart phone can capture more than one type of data and is easy to install.

Figure 5-2. The phone used in this prototype (Samsung, 2013)

5.2.1.1 Motion Data - Smart Phone with Built-in Accelerometer

The smart phone installed inside the fridge door senses the movement (raw data) when the fridge door is opened and then triggers the built-in camera to take photos (visual data). This method is preferred, rather than setting a timer in the camera to take a photo every given time, because it is more convenient for users to display only photos of an interaction between the user and fridge when an item is removed from or placed in the fridge.

5.2.1.2 Photos – Smart Phone with Built-in Camera

The raw data collected from sensing the movement every time the fridge door is opened was turned into meaningful visual photos of the fridge content. These visual photos will help users to retrieve what is stored in the fridge. This should be helpful when the user needs to remember what is inside the fridge to inform decision-making when planning or during food

shopping. These photos were uploaded to the dedicated website and were visible immediately to the users. The prototype relied on Wi-Fi access at the user's home to transfer data to the web.

Figure 5-3. Photos taken from the prototype in different timing. Both date and time are printed on each photo taken.

5.2.1.3 Mobile Application

To sense the movement and trigger the built-in camera automatically, a mobile application is needed. In this prototype, 'Motion Detector'[2], an android mobile app that is available at Google Play, was used. This app works as motion detection and uses the front built-in camera smart phone to take photos, print time and date on each photo, save photos, and upload them to the FTP server.

[2] https://play.google.com/store/apps/details?id=org.motion.detector&hl=en

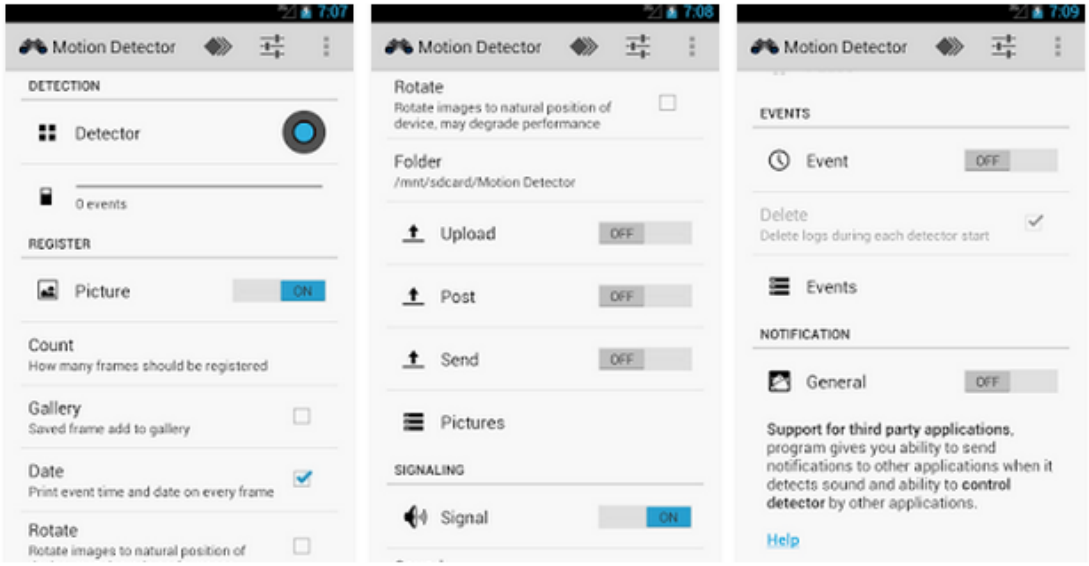

Figure 5-4. Screen shots of the mobile application

5.2.2 Setting up the Prototype

One Samsung smart phone was installed inside the fridge door using a mobile mount with a sticker. The phone was set up at an angle to take a photograph of the entire fridge contents. The back camera should face toward the fridge contents. The phone charger was plugged in to make sure the phone is on all the time.

Several strategies were used to ensure that the sensing was functioning properly. First, the mobile phone would be plugged into the charger all the time to make sure the battery does not die during the deployment. Second, the researcher could view a secure website of each household's current fridge contents and make any further adjustments needed.

Figure 5-5. First prototype setup

5.2.3 User Interface

The data generated by context-aware capture tools was uploaded to a dedicated website. This data is organized and indexed to allow easy access and aid user's memory to support decision-making related to food practices. The main challenge here is to turn raw data into more meaningful visual data. The user interface was designed to allow visual exploration, and grouping data was generated to allow users to browse and inform decision-making. Date and time were used to present data from the oldest to newest.

This interface was built in PHP using the WordPress platform[3]. Access to this interface is private; thus, each user has their own log in details with a unique username and password to secure personal data of the photos. The user interface of this prototype is simple and easy to navigate. The interface is divided into two parts. In the top left corner is the logo/name of the

[3] www.wordpress.com

prototype. In the main area, the visual photos are displayed in the thumbnails, from the newest photos on the top to the oldest in the bottom, with the latest eight photos. Each photo can be enlarged to a bigger size once the user clicks on it. Both date and time are printed on each photo taken. This issue was resolved by the mobile app installed on the smart phone that allowed this information to be created passively for each photo taken.

Figure 5-6. User interface of the first prototype shows the latest photos taken from the fridge

5.2.4 Evaluation

The aim of the first prototype is to explore how different types of data collection could influence users' decision-making process related to food practices using VBN theory lens. Little research has been done to examine the ways in which data could be collected for context-aware systems or to measure how such data could encourage user's changing behaviour and influence decision-making process.

5.2.4.1 Participants

One household (five participants) in total took part in this study: two females and three males. Participants' ages are between 23 and 33 years old. None of them had prior experience of using context-aware systems. All of the participants are professionals except for one undergraduate student. Participants were recruited through personal contacts and through different university newsletters in London.

5.2.4.2 Procedure

Capturing activities and interactions at the household level between people and the fridge, in terms of removing an item from or placing in an item inside the fridge, could support people to retrieve past interactions and inform future decision-making related to food practices. Thus, the effectiveness and necessity of context-aware computing must be examined. This could show that a new context-aware system is needed for domestic settings.

The researcher visited the household to install the prototype in the fridge and brought a smart phone, charger, and mount. First, the mount was placed inside the fridge door at a good angle where it could take a picture of the entire fridge contents; then the phone was set in the mount. The charger was plugged in and the household members were informed to make sure it was on all the time. Afterward, the mobile app was turned on to start motion detection. The researcher gave participants the consent form to sign and agree upon initiating the study (Appendix F). Moreover, participants were given a manual that includes username and password to access the website where the photos are displayed (Appendix G). This manual also includes email address and phone number of the researcher in case of an emergency. The prototype was left at the participants' household for a period of five weeks, and they were asked to use it as they desired. Participants were contacted twice via email through the study period to check if everything was going well.

At the end of the fifth week, the researcher visited the participants again in their household to terminate the study. A focus group was conducted with members of the household. They were asked many open-ended questions related to the effectiveness of this prototype

(Appendix H), if they used it when planning or while doing grocery shopping, or if they just relied on their memory to know food already purchased. The focus group took approximately 50 minutes. Then, the researcher went through the photos taken with participants for discussion and reflection.

5.2.4.3 Data Analysis

The focus group session was audio recorded and transcribed in written format as a full script. The analysis employed two types of coding: open coding and axial coding (Corbin & Strauss, 1990). The open code was used to label words and phrases by identifying events found in the script. The transcripts were organized into themes, categories, and examples using the VBN theory four variables to allow reoccurring topics or themes to emerge. The axial coding adapted to categories by combining inductive and deductive reasoning. Thus, themes were grouped into words and phrases.

Qualitative data was analysed using Dedoose, a web application that can manage and analyse data. Also, this app allowed the researcher to code, organize, and collect transcripts and related data. Each word, sentence, and paragraph was reviewed in the transcript and assigned one or more code. Many strategies were used to search for connections such as, direct quotes, and thematic organization. Transcripts were examined thoroughly to identify and note themes, which were given temporary titles and grouped with preliminary interpretations. The process was iterative, and as the analysis progressed, the themes were clarified, refined, and expanded. Thematical analysis (Creswell, 2009; Given, 2008) was applied to derive emergent underlying themes. The goal here is to measure how well the prototype meets individual needs and implement a process that focuses on understanding how the prototype was implemented and where it could be used.

After collecting the images of fridge contents the researcher went through the images with the participants during post deployment interviews to facilitate reflection and discussion. Visual ethnographic techniques (Pink, 2007) were applied to better understand the movement of food observed taken from fridge content. Later, the interview outcomes were cross-referenced with associated photos to corroborate what was said.

In addition, daily visits were tracked, and website traffic was analysed using Google Analytics. This enabled the researcher to see how many times participants visited and accessed the fridge contents online and the time spent per visit. Moreover, mobile versus non-mobile browser visits were tracked and analysed to determine if participants used it on the go.

5.2.4.4 Findings

The first prototype of the context-aware computing system successfully sensed and collected data in the home environment. This raw data turned into visual data (photos) and was presented to the user through a web user interface. Photos were uploaded and available immediately to the users via a dedicated website. This enabled the user to access and browse the captured data whenever they wanted. However, during the investigation period with real users, participants did not engage or use the prototype during food practices.

Over the five-week period, there were only two visits in total from mobile device. The average visit to the site lasted 47 seconds. Participants were apologetic that they had not engaged with the prototype more and in fact said they frequently forgot that the prototype was in their fridge or that the fridge content photos were available to them on the Internet when they did their grocery shopping. However, they liked the idea of the prototype and recommended it to their friends and families.

Interestingly, none of the participants tried to login and access images for planning their grocery shopping or during grocery shopping. They only accessed the photos to ensure the phone was still working. They argued that they did not need the prototype to help them memorize what was in the fridge and they did not need its support to inform decision-making related to food practices such as planning and shopping.

This data and the reasons why participants did not engage with the technology can be analysed in terms of VBN theory. As discussed earlier in Chapter 4, the focus is on three variables from VBN model: *contextual forces*, *personal capabilities* and *habits or routines*. *Attitudinal factors* are not covered because all participants elected in this thesis have a positive attitude towards sustainability and food waste.

With respect to the *habits or routines* variable from VBN theory, the first study confirmed that the technology did not change the participants' habits or routines neither to establish new habits of checking the images online prior nor during shopping. Participant P1 described his *personal capabilities* as organized and disciplined; thus, it was understandable that he never used the prototype to support shopping and he always remembered what was inside his fridge:

I never get a chance to access the images through my phone because I'm not that kind of person who does weekly grocery shopping, I usually do grocery shopping every two days, so I know exactly what's in my fridge.

P3 also explained that *contextual factor* such as limited space in the fridge prevented him from using the prototype:

I live in a shared house; I only buy limited items because we don't have enough space in the fridge.

Another *contextual force* is social status. Participants think that this prototype would be helpful for families, not for people who shared the same house, as explained here:

I think this project will be useful for someone who has a family, not in a shared house. I knew from my parents' house, our fridge is always full, and most of the stuff in the fridge is used (P4).

These findings show that the first prototype of context-aware persuasive technology did not encourage participants to change their behaviour. Nor did it influence their decision-making process. In terms of VBN theory, the influence of external *contextual forces* outweighed that of the context-aware persuasive technology, and the enhanced *personal capabilities* provided by the technology was not sufficient to change participants' *habits or routines*. This is illustrated by the participants' explanations as to why they did not engage with the system as discussed in the following section.

5.2.4.5 Discussion

The design and build of the first prototype of context-aware persuasive technology in the home environment has been presented. This technology could be installed in any food storage space in domestic settings (for example, in a fridge, cupboard, or pantry). The context-aware

computing sensed any changes in the home environment, collected data, and presented it to the end-users. The end-users accessed and browsed data captured to help retrieve past actions during food practices. This technology could inform a user's decision-making by presenting real-time data during real-time events. In this study, the technology was installed in a fridge (storage space in home environment). The prototype sensed the movement every time the fridge door was open and then took a picture of the fridge content. Pictures taken were uploaded to a dedicated website so the end-user could access and browse them. Accessing pictures could be when planning grocery shopping or during shopping to retrieve food available in the fridge, thus helping the user make an informed decision of the items to buy. This should prevent the purchase of multiple items and promote a sustainable lifestyle.

During the investigation, participants indicated that this early version of the prototype has no impact on their decision-making process related to food waste. There was no participation with the prototype, and participants said they did not need such a technology to help them memorize food available in the fridge to use while planning or grocery shopping thus did not change their behaviour. Enabling the VBN theory has highlighted a number of factors:

- *Contextual forces* included the facts that individuals had busy lifestyles and the number of housemates was large compared to fridge size. The size of the fridge limits the quantity of items that can be purchased or stored in the fridge to prolong shelf life. The greater the number of housemates, the less the available space in the fridge. These contextual forces outweighed the new contextual force represented by availability of information about the contents of the fridge
- *Personal capabilities* such as the influence of the novelty effect faded over time and having a good memory meant that participants did not feel the need use the technology. Some participants relied on their memory completely, without the need to use a technology. In this study, participants shopped every two days; therefore it was easy for them to remember available items.
- Establishing new *habits or routines* of checking the fridge content online prior or during shopping is difficult. This also is influenced by the factor of *personal capabilities* because participants already have an established *routine* of shopping which is not disrupted by the simple availability of information. Table 2-1 relates

VBN variables with environmentally significant behaviour. This study indicated that enhancing *personal capabilities* by introducing a new contextual force in the form of technology that makes information available is not sufficient to modify habits or routines so as to bring about significant behaviour change.

Due to the *contextual forces* and *personal capabilities* identified, the technology did not encourage changing participants' habits or routines. This raised an opportunity to modify the technology so as to encourage participants to change their behaviour. The first prototype required users to initiate interaction to change their behaviour and influence their decision-making process. The fact that *contextual forces* and *personal capabilities* outweighed the incentive to initiate interaction with the information indicates the need for an improved version of this prototype. This improved version could incorporate features such as pushing information over to users instead of them having to initiate interaction with the technology. This improved version of the prototype is presented in the next chapter (Chapter 6). Following development of the new version, another study was performed in Chapter 6 to explore the impact the improved technology on long-term behaviour change and decision-making process.

5.3 Chapter Summary

This chapter presents an investigation into how technology that provided access to relevant information might change behaviour so as to influence behaviour in a way that reduced food waste. The first prototype was designed and then built using a capture device installed in the food storage space. This prototype collected data (raw data), which was then turned into visual data (visual photos) to help retrieve past actions in food practices. A web user interface was designed and presented as well.

Findings from the investigation indicate that the participants did not need such a technology to influence their decision-making process, and, surprisingly, did not change their behaviour. The technology did not encourage participants to establish new *habits or routines* of examining the fridge content online due to *contextual forces* and *personal capabilities* such as busy lifestyle, fridge size and having a good memory. This prototype required an effort

from users to initiate interaction to support their decision-making. Therefore, an improved version of the prototype is presented in the next chapter (Chapter 6) to solve this issue and investigate it further.

Chapter 6 FridgeReminder: Design for Long-Term Behaviour Change

In the first prototype (Chapter 5), it was easy to capture data. This was the fundamental cornerstone of its process. During the investigation of the first prototype in chapter 5, all participants agreed that they did not need such a prototype to change their behaviour and influence their decision-making process, thus they did not initiate interaction with the prototype, which is described in details in section (5.2.4.4). This is due to various reasons identified through enabling VBN variables such as social circumstance and household fridge size. This type of prototype required the user to initiate the interaction.

Despite these limitations, the first prototype set the basis to build and design context-aware persuasive technology in home environment. The prototype successfully sensed and collected data in a domestic setting and then turned it into visual data that is easy to access and browse from a user interface. The results of the first prototype evaluation, refer to section (5.2.4.4), indicated that design improvements could encourage people to initiate the interaction, thus enabling further investigation into the effectiveness of context-aware persuasive to change user's behaviour and influence decision-making to better food practices and also could promote sustainable lifestyle.

This chapter presents the process of redesign and rebuild to create an improved version of the first prototype that encourages people to interact with the prototype and to establish an appropriate and suitable user interface that permits interactive browsing. This prototype should retrieve past interactions through visual data and would encourage people to respond and react to that data to gain further detailed information about their past actions. New ways have been identified for users to interact with the prototype. For example, several functions and features need to be integrated in the first prototype to encourage interaction with users.

The second prototype, called 'EyeFridge', is presented in this chapter. EyeFridge is a new passive context-aware persuasive technology that collects, presents, and sends data to users through FridgeReminder, without requiring users to initiate interaction to take full advantage of the system. This system also recommends alternative suggestions based on the collected data to support decision activities.

This is based on the Wizard of Oz approach (Kelley, 1984) through the researcher who sends suggestions or alternatives manually from the researcher's phone to the user's phone based on the data (photos) collected. The suggested actions or alternatives are intended to influence the fridge user's decision-making process and ultimately change the user's behaviour. Specifically, the researcher examines photos collected daily and identified items available in the fridge. Then notifications are sent suggesting actions/alternatives such as reminders of items missing from the fridge. Recipe suggestions based on items available in the fridge are also sent and messages to remind participants to re-engage/re-use the system are sent if there is no activity for more than two days. How the Wizard of Oz approach was used in the context of the VBN model to investigate user behaviour in relation to food purchase and use is explained further in sections (6.4.1.2) and (6.4.1.3). The Wizard of Oz approach helped raise users' awareness of food knowledge through letting the user initiate the interaction or pushing the information needed.

In relation to VBN theory, this will impact the variables related such as *personal capabilities* and *habits or routines*. The first study showed that simply making information available was not enough to modify participants' habits or routines. By sending notifications to participants, the Wizard of Oz approach aimed to strengthen the *contextual force* represented by the fridge technology to the point where it brought about the desired change in behaviour.

The user interface of EyeFridge presents the captured data immediately based on the physical activity-taking place to be browsed. The system captures data about everyday interaction in the food storage space (in this case a fridge) from sensors placed in that space. Pushing information over to the user via FridgeReminder (notifications and reminders) could change behaviour through creating new *habits or routines* to inform decision-making and promote a sustainable lifestyle.

Although EyeFridge addresses environmental issues related to food waste, the present work does not focus only on sustainability research but uses it as a domain area to investigate approaches borrowed from social psychology to change behaviour, raise awareness and engagement, and influence decision-making process through digital design (Cialdini and Goldstein, 2004).

6.1 Active vs. Passive Context-Awareness

Schilit et al. (1994) introduced the concept of context-aware computing. Since then, numerous definitions have been presented. Cheverst et al. (2001) studied whether context-awareness should push information over to the user or the user should initiate interaction. However, Erickson (2011) believed that context aware applications should be push-based applications and that user should never initiate interaction. Active context-awareness measured sensor data and then changed the user's content autonomously. For example, when the user travels to a different time zone, the mobile phone changes its time automatically. However, passive context-awareness presents the updated context to the user and allows the user to be in control (Chen & Kotz, 2000). For instance, a mobile phone reminds the user of the different time zone and asks whether the time should be updated or not when the user travels to a different time zone.

For this second prototype investigation, the concept of passive context awareness was used to simulate a technology that actively initiates interaction with the user and to adapt passive context awareness to create an active technology that nudges the user.

6.2 Requirements for Passive Context-Aware Persuasive

This section provides some general requirements identified for building a passive context-aware persuasive. The researcher believes that in the future, passive context-aware persuasive technology will be highly integrated in our daily lives and massively deployed in home environments. This future technology shall be available and user-friendly for simultaneous users (household members), who can access the data required easily and directly within the

website (or the data could be pushed to the users). A set of requirements is identified for future a passive context-aware persuasive that supports decision support in the home environment. These requirements are divided into three distinct categories: requirements for device, requirements for design, and requirements for performance.

6.2.1 Requirements for Device

- **Wireless communication:** Data collected should be transferred to the database on the webserver through Wi-Fi connection.
- **Plug and play:** This feature should operate seamlessly in the home environment. This means that the prototype should be installed and ready to operate immediately without installing further software.
- **Ad hoc interaction:** Minimal prior knowledge about prototype and sensors should be needed. Driver installation and specific applications should not be required.
- **Uniform access:** Prototype services should be well understood and easily accessible. This enables their smooth integration in the home environment.

6.2.2 Requirements for Design

- **Web user interface:** The user interface should allow management and control of the prototype, as well as easy interaction with features by household members.
- **Mobility:** Users should be able to access data on the go (such as through their smart phone).
- **Real-time information:** The prototype must inform household members in real time about their interactions with the food storage space (for example, showing placing or removing an item by providing photos of fridge content).
- **Layered architecture:** Such design would facilitate, promote, and accelerate the development of passive context-aware persuasive, tailored to solve specific challenges in-home environment.
- **Easy installation:** The prototype must be easily installed on objects such as the fridge in the home environment.

- **Direct access for household members:** Users should be able to use and access the prototype without the need for installing additional software. This would ensure the usability of the prototype and would minimize the entry barriers for users.
- **Support notifications and reminders:** The researcher, who acts as an agent using the Wizard of Oz approach, can program tasks for future execution, and notifications can be triggered in cases when important events are sensed.
- **Suggest alternatives:** The researcher is able to suggest alternative decision support based on the data collected. The researcher accesses the collected data, suggests alternatives, and presents it to users through web interface such as suggesting recipes based on food content.
- **Responsive design:** The web user interface should be responsive to provide easy reading and navigation to users who access it through different devices such as smart phone or tablet.
- **Concurrent:** User should be able to interact simultaneously with their prototype, without loss of requests due to concurrency in the home environment.

6.2.3 Requirements for Performance

- **Battery lifetime:** The prototype must not consume much battery during operation. Household members would not be willing to change batteries frequently.
- **Scalability:** The prototype must support a large number of users, who may interact concurrently with their prototype.
- **Response time:** Smart techniques must be employed for achieving satisfactory performance. Response times must be less than a second, even when numerous users interact with prototype.
- **Push information time:** Pushing information should require minimum time from prototype to users and should be sent immediately after sensing changes in the home environment.

6.3 Architecture of Passive Context-Aware Persuasive Decision Support System

In this section, the passive context-aware persuasive technology of the second prototype is described, based on the requirements defined in the previous section. In addition, the general design and implementation of the prototype assumes the presence of a food storage space in the home environment and household members who may interact simultaneously with their home environment.

The prototype follows a modular architecture, and it consists of four principal layers: the *data generation layer* is responsible for sensing and collecting data; the *data communication layer* is responsible for uploading data to the database; the *data processing layer* is the system's central processing unit, and the *data presentation layer* presents data and services to users. In Figure 6-1, the prototype architecture is illustrated.

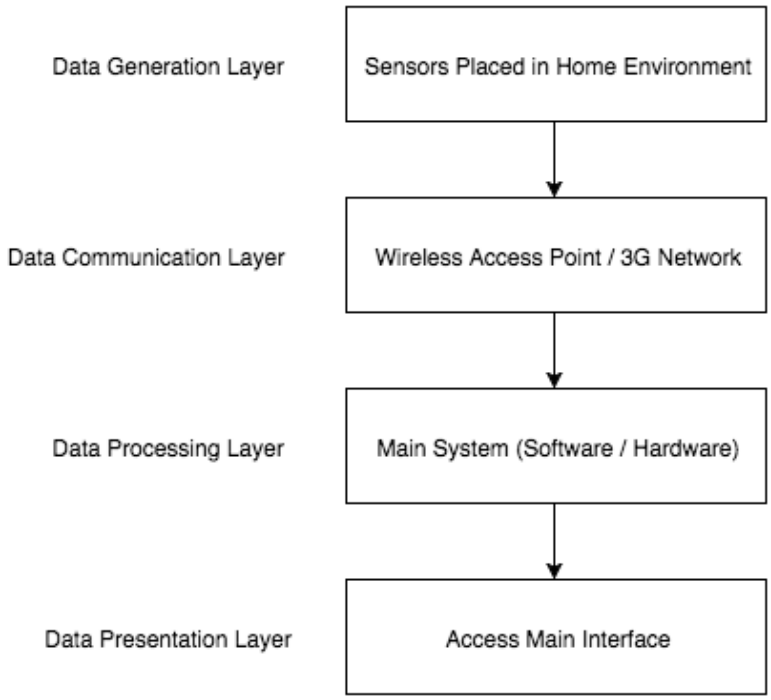

Figure 6-1. Passive context-aware architecture

In the generation layer, sensors and cameras collect raw data from the home environment and turn it into visual meaningful data such as photos. Sensors and cameras could be placed on

objects in domestic settings (food space storage) such as fridge, freezer, pantry, and cupboard. The communication layer connects and transfers between the data collected to the processing layer, which holds the database, and then presents it to end-users through a wireless connection or 3G/4G network. The processing layer is the soul of the system. It holds the logged and collected data, which runs in the background constantly. The presentation layer presents the data collected to the prototype from the web. It is the layer responsible for interaction with users and is separated from the rest of the system because it is the most extended part of it. The web server allows users to interact with the prototype through a website.

6.4 EyeFridge System

With regard to all previous types of data captured in the first prototype, more features should be integrated, such as pushing information to the user to make the collection more powerful, reliable, and meaningful. To accomplish that, the user interface design was extended to integrate additional features and make the system more intelligent by using the Wizard of Oz approach to suggest recommendations and push information to users. Figure 6-2 illustrates the infrastructure of EyeFridge.

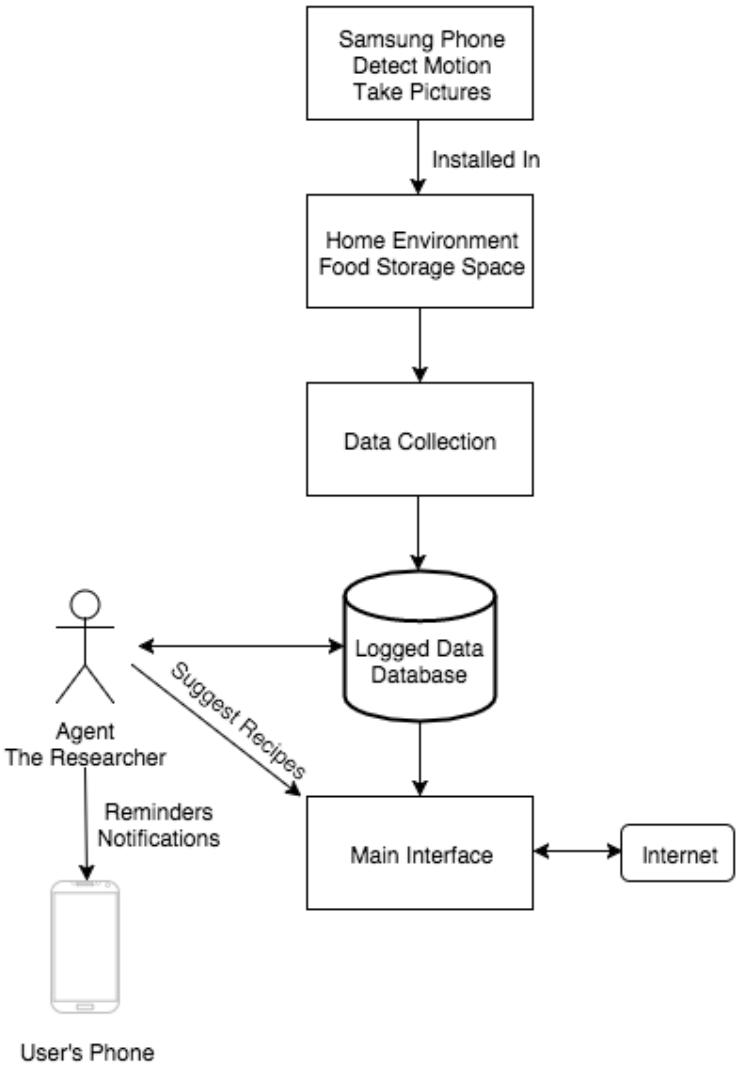

Figure 6-2. EyeFridge infrastructure

In this prototype, the challenge is to make users engage with the data that has been captured. How can we persuade the user to initiate interaction with the system to enable investigation into the effectiveness of passive context-aware persuasive to influence decision-making process in domestic settings?

A Samsung smart phone was used as a capture and sensing tool. The phone, which was installed inside the fridge door, features a built-in accelerometer that senses movement every time the fridge door is opened. The motion sensing then triggers the built-in camera to take a picture of fridge content. This sensing method and the prototype setup (Section 5.2) are identical to those used in the first prototype.

6.4.1 User Interface

The primary challenge in designing a user interface for context-aware data gathered by multiple sensors is to turn raw data about interactions in the home environment into more meaningful data. The user interface of EyeFridge was designed to allow visual exploration, grouping of data, recommendations of action, and pushing of information to users so that users could browse and ultimately support decisions in real-time events. This means the captured data must be uploaded and organized to be usable.

Context-aware computing should be more productive, approachable, simple, and fun, while being able to accomplish the users' goals and allowing them to annotate their own data for later reflection.

The EyeFridge interface was built in PHP using the WordPress[4] platform. Access to this interface is private; thus, each user has their own login details with a unique username and password, with secure personal data for the photos. The user interface of this prototype is simple and easy to navigate. The interface is divided into three parts. In the top left corner is the logo or name of the prototype. In the main area, the main content of the page is displayed. Between the header and the content is the navigation bar. The EyeFridge interface consists of several functions to foster day-to-day engagement. These features are FridgeGallery, FridgeRecipe, and FridgeReminder.

6.4.1.1 FridgeGallery

The photos taken from the mobile phone installed in the fridge are displayed as a photo stream, from the newest photos on the top to the oldest on the bottom. Each image can be enlarged for a better view, and both date and time are printed on each photo taken. This issue was resolved by the mobile app installed in the smart phone that allowed this information to be created passively for each photo taken. Users can access the latest eight photos using their smart phones, tablets, or computers. The display of pictures aims to retrieve past interactions

[4] www.wordpress.com

between participant and fridge of taking from or placing an item in the fridge. It also supports participants in their everyday food planning and shopping practices. Figure 6-3 shows the homepage of EyeFridge application website and FridgeGallery.

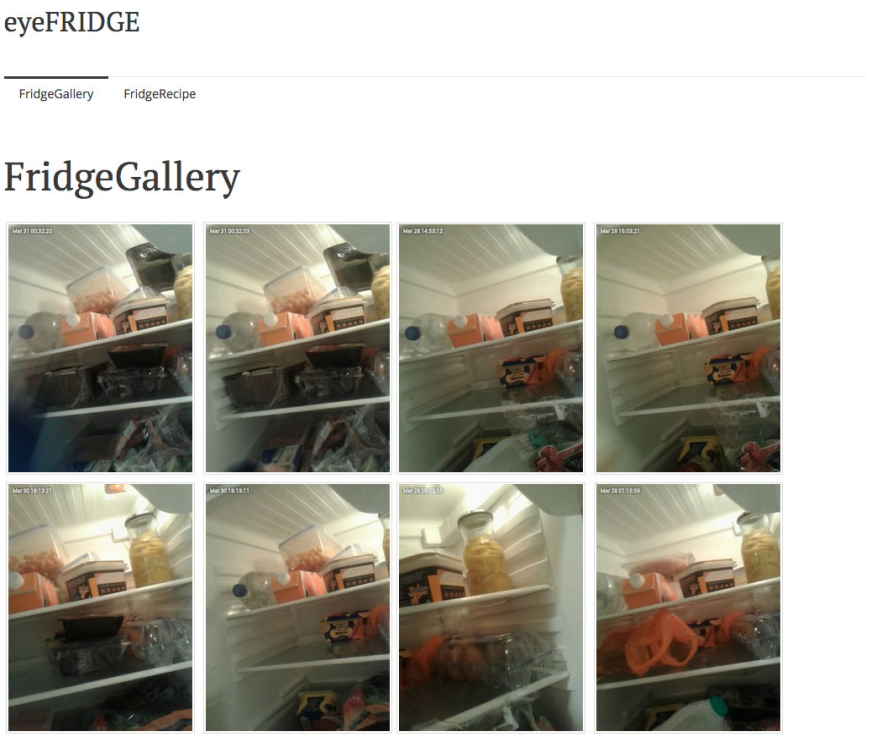

Figure 6-3. Homepage and FridgeGallery

6.4.1.2 FridgeRecipe

The FridgeRecipe function generates recipe recommendations based on the fridge content. The Wizard of Oz (Kelley, 1984) prototyping approach is used to identify items available in the fridge. The Wizard of Oz was used by the researcher through looking at the photos taken of the fridge content every day from the administration panel. Then the researcher based on the available food in each household fridge generates recipes. The researcher searched MyRecipes[5] Website for recipes based on the ingredients identified, and assigned recipes to each household. Recipes are generated every time participants stock their fridge.

In relate to VBN theory, the aim is to help participants to increase their *personal capabilities* such as creativity of using what is available in the fridge and leave users in control to reduce the amount of food waste. In addition, creating new *habits or routines* of checking these recipes and trying them. However, the findings shows later in section (6.5.4.2) those participants were not keen to engage with this feature

[5] www.myrecipes.com

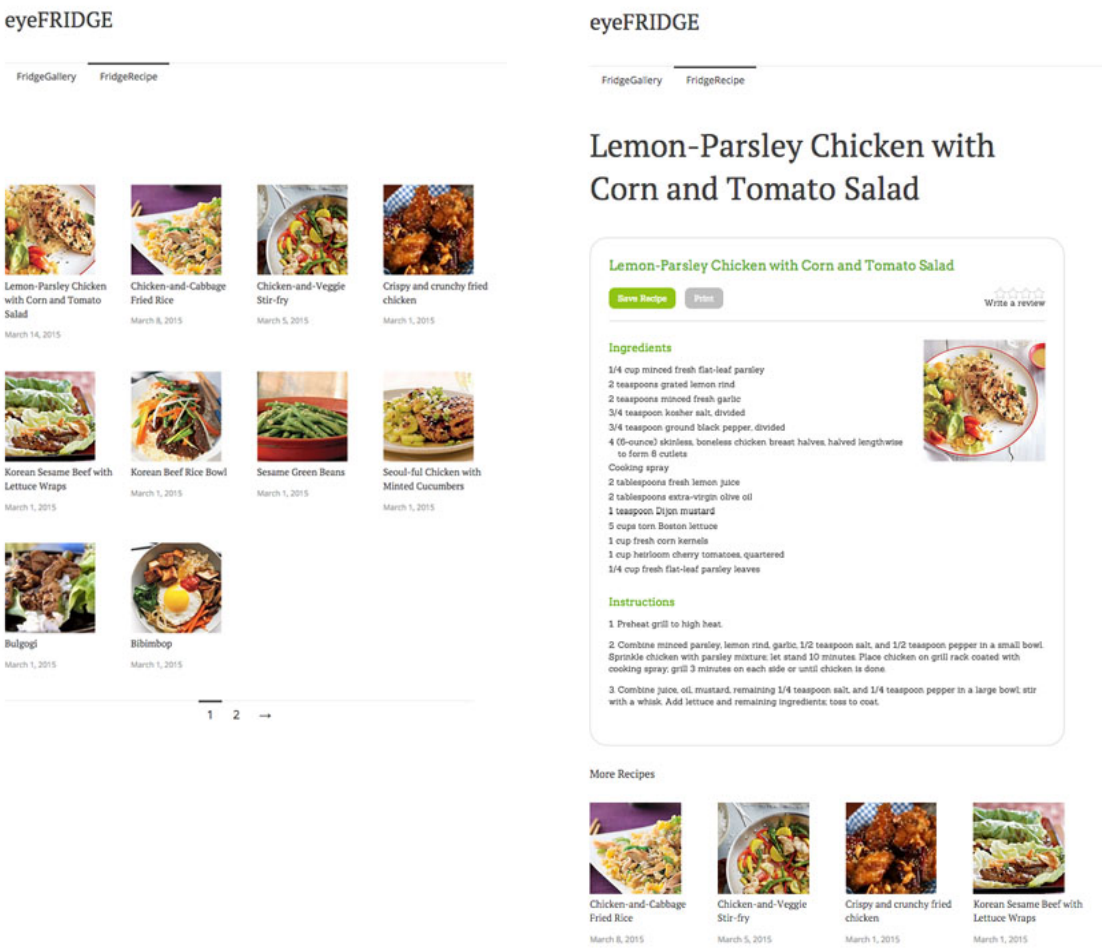

Figure 6-4. Group of recipes generated based on fridge content (left) and one of the recipes (right)

6.4.1.3 FridgeReminder

The idea of sending reminders was previously proposed as future work for BinCam (Thieme et al., 2012), but was not developed and tested with real users. In this thesis, the FridgeReminder feature was integrated into the EyeFridge app to evaluate this feature further in terms of re-visitation and long-term engagement. Participants received push notifications to their personal smart phones of the following events:

- Reminder to re-use the application if the user did not use the app for more than two days.
- Items that are running out.
- Recipe suggestions based on fridge content.

Classification	**Notification message**
Items running low	Banana is running low.
Recipe suggestions	Check out this new added recipe on EyeFridge website.
Reminder to engage	You have not logged in to EyeFridge website for a while. We miss you!

Table 6-1. Sample of messages sent to participants during the study

One notification was sent every two days during the study period of five weeks. The Wizard of Oz (Kelley, 1984) prototyping approach was used to send reminders and notifications to users' smart phones. The reminders were sent manually to participants' phones by the researcher using Whatsapp[6] from the researcher's phone to participant's phone. Participants gave their phone numbers to the researcher before conducting the study. The researcher made sure that Whatsapp installed on participants' phones and they were regular user of Whatsapp, thus enabling the user to receive notifications. The researcher checked and looked at the photos taken of the fridge content daily and compared them to see if items were running out

[6] www.whatsapp.com

that needed to be purchased, and then sent a reminder from the researcher's phone to the participant's phone. Also, the researcher sent notifications of recipe suggestions based on the ingredients displayed in the pictures as described previously in section (6.4.1.2). Table 6-1 shows examples of messages sent to the participants. In relation to VBN variables, this will impact the *personal capabilities* variable in regards to raising participant's awareness of food knowledge and creating new habits or routines.

Participants were asked to reply to notifications with the word 'OK' if they followed up with a decision or action. For example, a participant might get a notification of an item running out on the way home from work, and then pop into the shop to buy the item needed. This will enable measurement of the effectiveness of notification on consumer decision-making. Participants will reply to the whatsapp message with the word 'OK'. Figure 6-5 illustrates how participants received notifications and applied with word OK if followed by an action or decision.

In this way, a human researcher, enabling investigation of end-user interaction with the technology, simulated the behaviour of an intelligent fridge. The goal is to examine if reminders and notifications supported participants' decisions on food planning and shopping and change their behaviour. Also, the study will determine if reminders and notifications improved waste outcome and engaged the user more to use the EyeFridge on a daily basis. Findings indicated later in section (6.5.4.3) that notifications encouraged change behaviour and decision-making process.

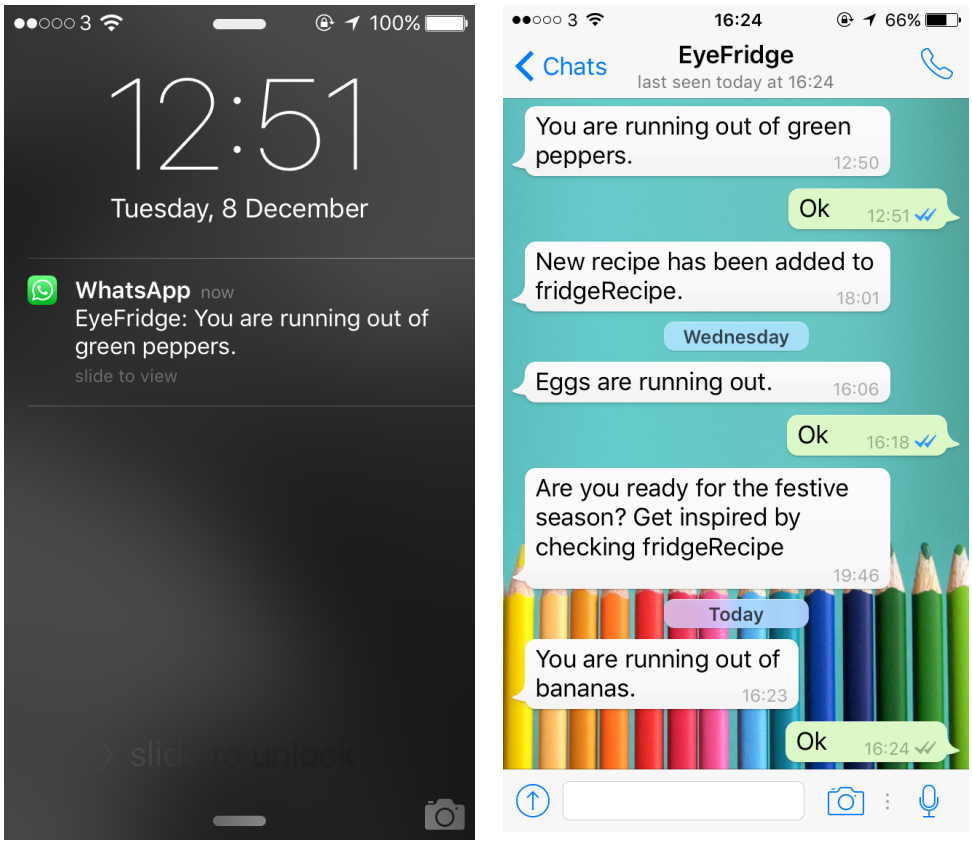

Figure 6-5. Home screen of participant's phone shows the notifications received from EyeFridge (left) and group of notifications received on whatsapp with some responses from participant (right)

6.5 Evaluation

The aim of the investigation is to explore how the collected data could change behaviour through raising awareness, reflection, and influence consumer decision-making process related to food practices by enabling the VBN theory lens. In addition, it explores the impact on long-term engagement of sending information to the user instead of letting the user initiate the interaction with the prototype.

6.5.1 Participants

Five households in total took part in this study. There was only one participant interviewed per household who was also an active user. The participants were two females and three

males. The females were undergraduate students and one professional, and the males were PhD student and two undergraduate students. Participants were recruited through personal contacts and through different university newsletters in London.

No.	Sex	Age	Household type	Number of people in household	Social status
P1	Male	32	Shared flat	3	PhD student
P2	Female	20	Shared flat	4	Undergraduate student
P3	Male	21	Shared flat	5	Undergraduate student
P4	Male	21	Student accommodation	5	Undergraduate student
P5	Female	25	Shared house	5	Sales assistant

Table 6-2. Description of each participant involved in EyeFridge study

6.5.2 Procedure

Capturing activities and interactions at the household between people and the fridge in terms of items taken out or placed inside the fridge could support reflection, remembering items inside the fridge, and influence future decision-making process related to food practices. This could ultimately promote sustainable lifestyle in the food waste domain. Thus, the effectiveness and necessity of passive persuasive context-aware technology that includes notifications and reminders must be examined to provide evidence that this new technology could change behaviour for domestic settings.

The researcher visited the household to install the prototype in the fridge. Items brought for the installation included a smart phone, charger, and mount. First, the mount was placed inside the fridge door, at a good angle for taking a picture of the entire fridge content. Then the phone was placed in the mount. The charger was plugged in, and the household members

were informed to make sure it was on all the time. Afterward, the mobile app was turned on to start motion detection.

The researcher gave participants the consent form (Appendix F) to sign and agree upon initiating the study. In addition, participants were given a manual that includes username and password to access the website where they can view the photos (Appendix I). This manual also included email address and phone number of the researcher in case of emergencies. The prototype was left at the participants' household for a period of five weeks, and the participants were asked to use it as they desired. Participants were contacted twice via email through the study period to check if everything was going well.

At the end of the fifth week, the researcher visited the participants' household again to terminate the study. Interview sessions were conducted and participants were asked many open-ended questions related to effectiveness of this prototype (Appendix J), if they used it when planning or while doing grocery shopping, or if they just relied on their memory while shopping. The average time of interview was 30 minutes. Then, the researcher went through the photos taken with participants for discussion and reflection.

6.5.3 Data Analysis

Interviews were recorded and transcribed in written format as a full script. Qualitative data was analysed using Dedoose. Additionally, daily visits were tracked and website traffic was analysed using Google Analytics. During the analysis, VBN theory used to study the effective of the technology on behaviour change and influence decision-making process. These data analysis methods were described in details in the previous chapter (section 5.2.5).

To measure the effectiveness of notifications and reminders on consumer decision-making, if participants responded to them throughout the study period, they were asked to reply to notifications and reminders with the word 'OK' if they followed it by an action or decision.

6.5.4 Findings

An important aspect of the study was the way it evolved from a simple capture of images

toward more active intervention in which the researcher simulated a smarter fridge. Overall, participants liked the idea of EyeFridge and would recommend it to friends and family. The FridgeReminder feature (pushing notifications and reminders to user's phone) was described as enjoyable and useful to initiate and promote engagement with the system.

6.5.4.1 Web Traffic

Over the five-week period, a total of 178 visits were made to the EyeFridge application, with 29 of these visits from mobile devices and 1 visit from a tablet device. Participants mostly visited the app from non-mobile devices and reported a number of reasons to visit the app as shown in Figure 6-6, including: to ensure it was still working and uploading pictures to the website; to show the project to friends; and to plan grocery shopping in advance. This indicated that participants displayed photos online prior to their shopping to plan in advance. Participants are referred to the subject number: for example, P1 is the first participant interviewed.

The most frequent users of the EyeFridge app were P1, P3, and P4; they regularly visited the EyeFridge app to support planning and shopping practices. The post deployment interviews indicated that EyeFridge had an impact on remembering available food in the fridge. Most participants said it was useful with frequently consumed items such as milk. The major factor currently leading to food waste in households is that consumers do not memorize all the available food in the fridge at a given moment (e.g., during food shopping). Visual images helped participants to remember the food they had in the fridge. Figure 6-7 illustrates number of online visits to the application for both prototypes.

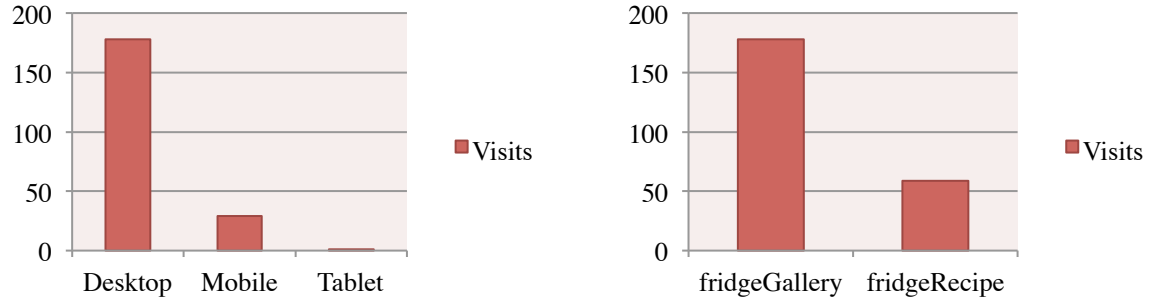

Figure 6-6. Devices used to access EyeFridge website over the course of the study (left) and total visits for each activity (right)

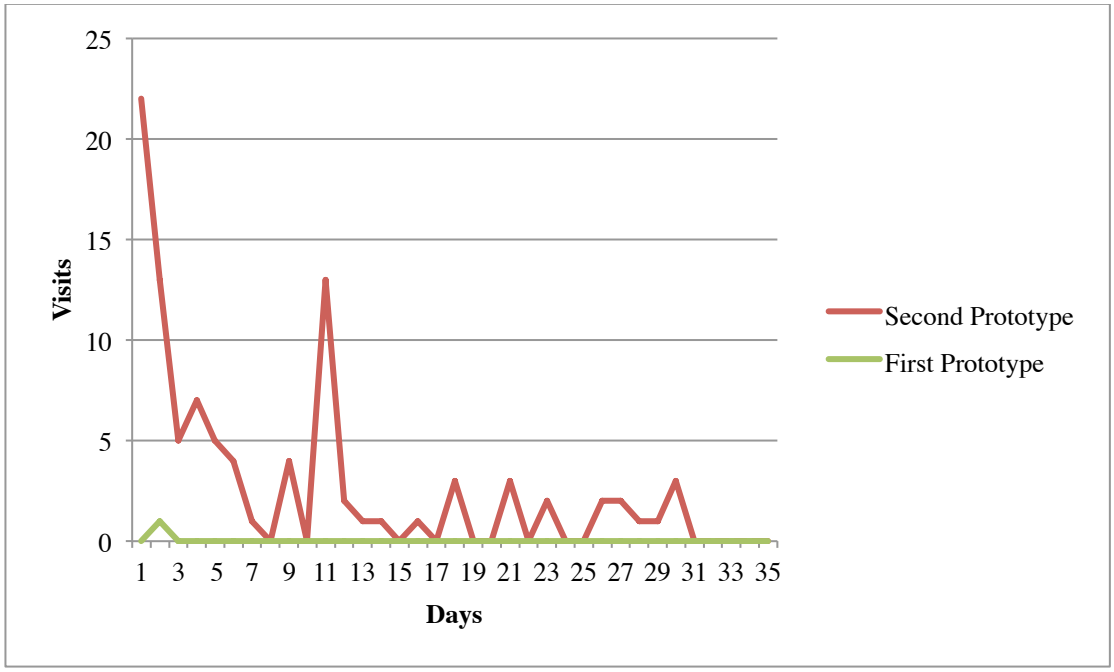

Figure 6-7. Re-visitation increased by more than 60% in the EyeFridge study (with notifications) compared to the first prototype study (without notifications)

6.5.4.2 Compare tracking visits with item movements in the fridge

The researcher went through each household's daily visits to the website using Google Analytics and compared these activities with photos taken of the fridge content and with what participants has said during the interviews. Changes such as movements of items in the fridge and restocking of food in the fridge were noted with examples of some these photos. In relation to VBN theory, the focus during the data analysis is on three variables of VBN out of

four: *contextual forces*, *personal capabilities* and *habits or routines*. However, the *habits or routines* variable is the ultimate factor that encourages behaviour change and influences decision-making processes related to planning and shopping practices as shown later in findings (section 6.5.4.4). *Attitudinal factors* are not mentioned in the data analysis because all participants chosen for this study have positive attitudes and beliefs towards sustainable lifestyle.

The post deployment interviews indicated that EyeFridge had an impact on remembering available food in the fridge. Most participants said it was useful with frequently consumed items such as milk. The major factor currently leading to food waste in households is that consumers do not memorize all the available food in the fridge at a given moment (e.g., during food shopping). Visual images helped participants to remember food they had in the fridge. Three of the participants had also noticed some reduction in the household food waste. The actual data available was the same for the first and second prototypes, but the user engagement with the data was greater for the second prototype. The 'pushes' from the fridge made a noticeable difference to user engagement. The impact of notifications and reminders on behaviour change and decision-making will be discussed further in section (6.5.4.4).

Studying the web traffic of the first household, P1 visited the website on 26 January; on the photo taken on 26 January, there is a change compared with the previous photo taken—the fridge has been restocked with banana. Also, there was another visit on 29 January, and the photo taken on that date shows that the fridge was stocked with red peppers as shown in Figure 6-8.

EyeFridge also offered a very practical prospect to show that technology might help with food shopping practice. Accessing photos online allowed some of the participants to engage with more than one food related practice; for example, with planning and shopping. An example of this is that P3 valued the support of EyeFridge to buy what he needed without the need to memorise available food in the fridge, and he reported accessing photos online to check what he had to buy. P3 started checking the images because of the notifications received. In terms of VBN theory, notifications strengthen the *contextual force*, for example, the fridge technology, to the point where *habits or routines* are modified. Notifications

encouraged him to develop a new *habit or routine* of checking what is inside the fridge online through the application website. The impact of these notifications on habits or routines will be discussed further in section (6.5.4.4):

When I am at the supermarket I did look at the pictures, or on the way to the store or while I'm on the train after university I pop to the supermarket and check what I need have a look what is in there.

On 8 February, P3 visited the website prior to shopping. The photo that was taken on 8 February shows that the fridge was stocked with vegetables compared to the photo taken on 6 February. The figure shows no activity from the second week to the third week because the participant was away.

Figure 6-8. Comparison from Google Analytics of visit to the website with photos taken from P3's fridge

P1 also added regarding the impact of accessing photos online prior to food shopping. P1 confirmed that checking photos online when he is at university prior shopping helped him raise awareness of available food in the fridge and changed his behaviour by developing a habit or routine of planning and examining what is inside the fridge online. Enabling the VBN theory lens illustrates that participants established new habits or routines of planning and checking the fridge content online prior shopping:

I always check what's inside my fridge before grocery shopping from my laptop. I really liked the concept of this technology.

He also indicated that notifications influenced his decision-making regarding planning practice, which will be covered in details later in section (6.5.4.4).

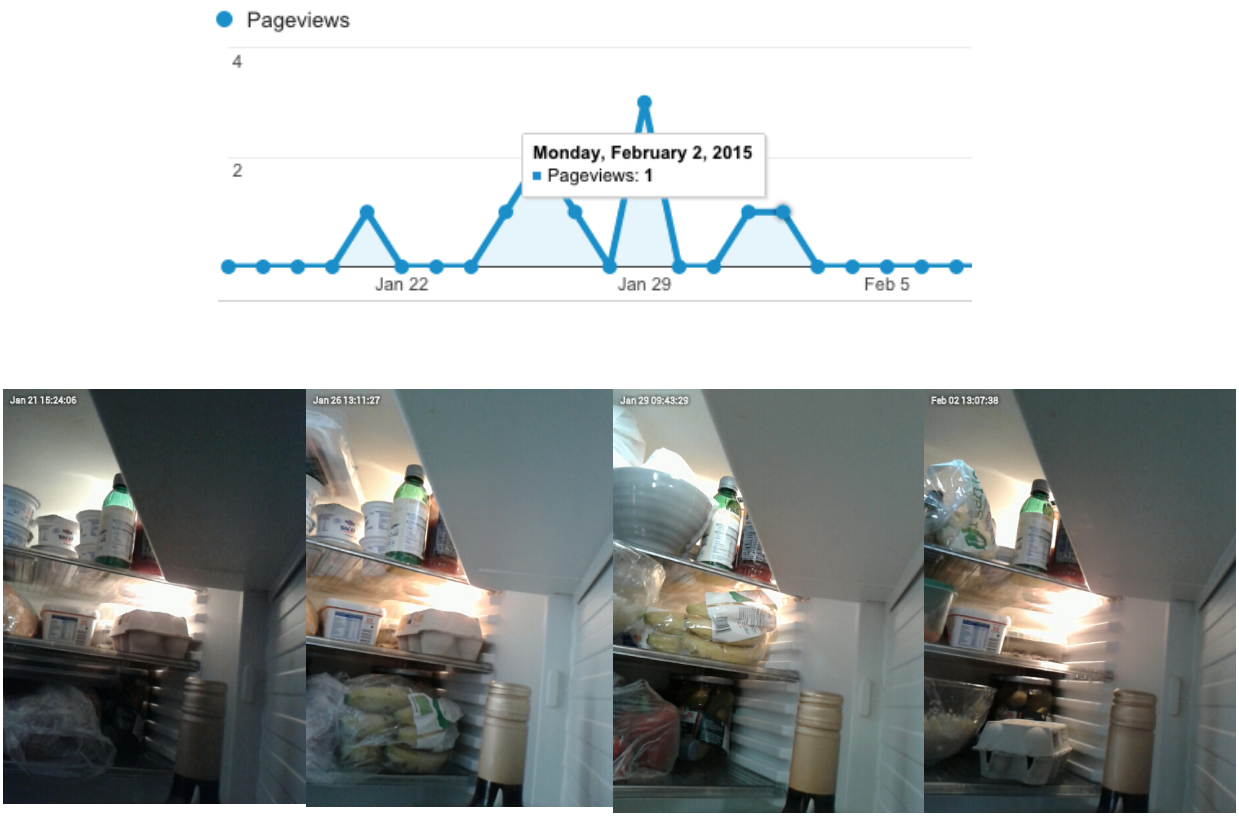

Figure 6-9. Comparison from Google Analytics of visit to the website with photos taken from P1's fridge

P4 visited the website on 3 March and then filled the fridge with eggs, noodles, chicken, and vegetables. Another visit on 22 March and the photo taken on 23 March show that the participant filled the fridge with chicken, meat, and other items. He said during the post deployment interview that he accessed photos online prior shopping practice, however, he stopped accessing the photos in the last two weeks of the study as shown in Figure 6-11 and started to trust notifications received. He also confirmed that notifications had an impact on his decision-making process during planning and shopping practices as he always read notifications received therefore changed his behaviour of establishing new habits or routines.

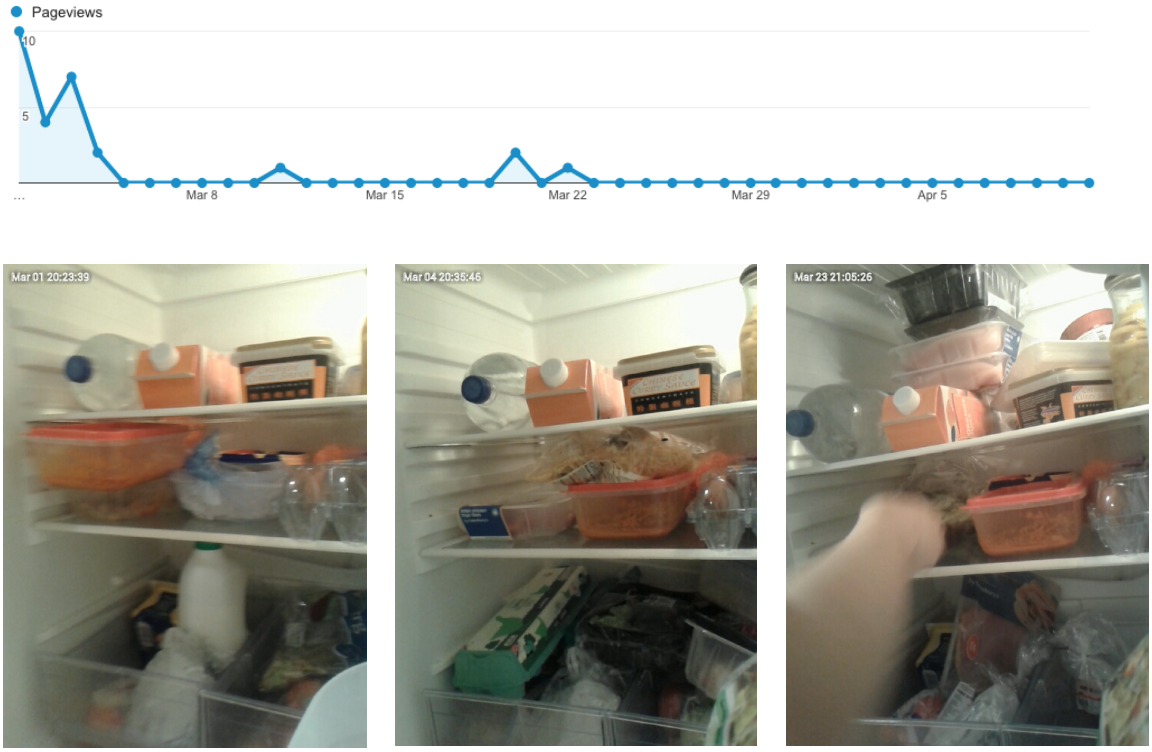

Figure 6-10. Comparison from Google Analytics of visit to the website with photos taken from P4's fridge

In comparison, P2 and P5 did not access the photos online to support food practice decisions as shown in Figure 6-9. Both said during the closing interviews that they simply forgot about the prototype and about having a camera inside their fridges. Through the VBN theory lens, this is due to their *contextual forces* such as busy lifestyle prevented them from checking the images online. They also said the only few times they visited the website was to ensure the prototype is still working and uploading pictures:

I kept forgetting it (EyeFridge) was there. It just seems like something that I don't have time for. When I do shopping I'm just like in a rush to get it done. I don't even check what's in the fridge (P2).

However, P5 said she relied on reminders and notifications when it comes to interaction with the prototype. This shows that notifications and reminders helped create new *habits or routines*. She said that reminders helped her with planning and shopping activities. Therefore, there is no need to compare daily visits with photos taken from their fridges.

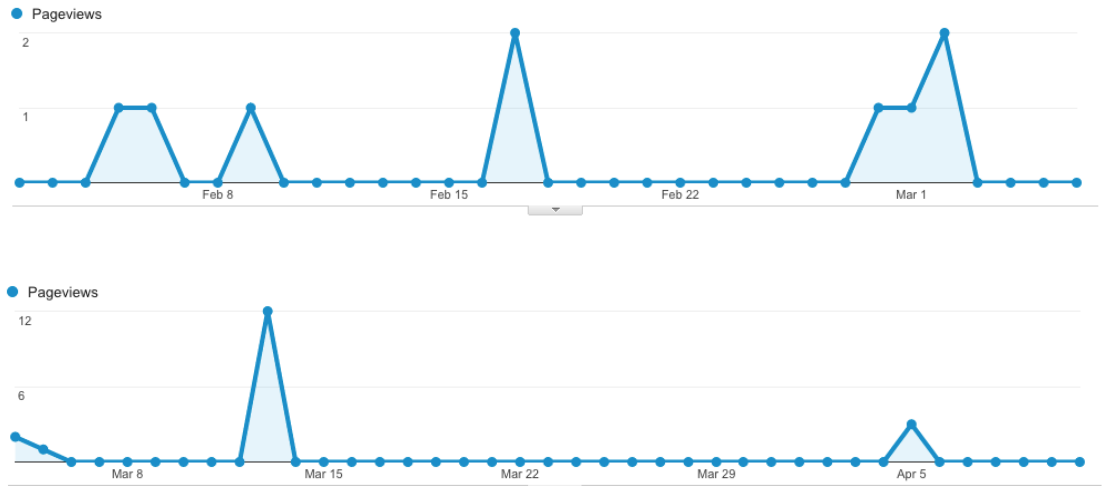

Figure 6-11. Total daily website visits from P2 (above) and total daily website visits from P5 (below) taken from Google Analytics

6.5.4.3 Recipe Recommendations and Creative Cooking Options

Participants' opinions on the FridgeRecipe were mixed. Participants liked the idea of recipe recommendations and found it interesting. P3 explained how it was easy for him to follow the recipes:

The recipes are good; you can see what's in there and if you don't have an item you can go and buy it. I tried one of the recipes.

Moreover, this feature made P5 feel like it was personalized to her needs and preferences:

I liked the recipe suggestions. I noticed there are Bulgarian recipes (I'm Bulgarian), which I was really impressed; felt the fridge is personalized to my needs.

Although participants liked the idea of generating recipes based on the fridge content, they all agree they were less keen to engage. This feature did not encourage the participants enough to create a new *habit or routine* of checking recipes available and try any that might in return helps promote sustainable lifestyle. P2 explained:

I really liked it! Sadly, I didn't try cooking any of the recipes.

She also did not engage with this feature due to her cooking skills:

I did look through the recipes; it is just I'm not that much of a cook, but it was really interesting.

In terms of VBN theory, *personal capabilities* raised participant's awareness of food available and raised creativity of what to cook with what. However, this did not lead to create new habits or routines of cooking or trying recipe suggested. This confirm that *habits or routines* variable is the ultimate behaviour change aspect, which confirmed the earlier findings in section (6.5.4.2).

6.5.4.4 Receiving and Reviewing Notifications and Reminders

Because the first prototype failed to engage and initiate interactions with participants, notifications and reminders were introduced in the second prototype to investigate if it has an impact on long-term behaviour change through raising awareness, reflection, and influence decision-making process related to planning and shopping practices.

Notification message	**Total sent per participant**	**Response of each participant**						
		P1	**P2**	**P3**	**P4**	**P5**	**Mean**	**SD**
Items running out	10	9	1	8	8	10	7.2	3.56
Recipe suggestions based on ingredients available in the fridge	6	0	1	1	0	0	0.4	0.54
Reminder to re-engage with EyeFridge system (for example, access photos online)	2	0	0	0	1	0	0.2	0.44

Table 6-3. Total notifications sent to participants and response rate

The post deployment interviews indicate that all participants enjoyed receiving notifications and reminders of real-time events to their phones, as they found that this feature made it easier to interact with EyeFridge. The reminders and notifications regularly updated participants automatically over time, and participants kept reviewing the changes and made decisions based on them. This activity of receiving and reviewing notifications became more iterative. All participants indicated they read all the notifications and made a decision or an action after receiving some of these notifications. The actions were to pop in to the store to buy the missing item notified about, cook a recipe based on suggestion received, or re-engage with the app to access photos online. A total of 90 push notifications and reminders were sent to participants and total response of 57 notifications. Table 6-3 shows total number of notifications received per participants and how many respond back to each notification. Participants enjoyed receiving notifications about items running out; they found it useful prior to grocery shopping, and it had the highest response rate, with a total of 36 responses. P3 explained how he established a new *habit* of reviewing notifications received on his way home, and then stopped at the shop to buy the items needed:

I read each notification I received. Reminders are helpful. On my way home I got one of these notifications about running out of items, then pop into the store to buy them. It feels like you [the researcher] are talking to me.

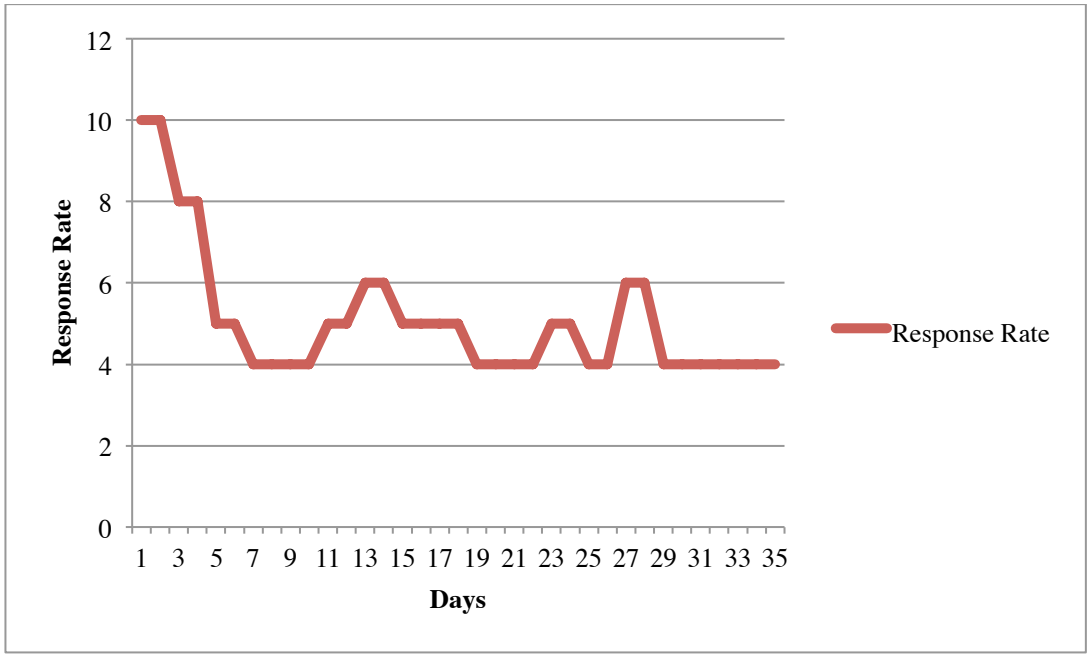

Figure 6-12. The response rate of notifications throughout the period of study shows that notifications raised consumers' awareness and reflection to produce better decision-making behaviour

Participants also explained they sometimes did not make a decision after receiving these notifications due to *contextual forces* such as their busy schedule or due to *personal capabilities* because they simply forgot about it. P2 said:

Sometime I forgot to buy the missing item I have been notified.

P4 also added:

I receive some of these notifications while I'm at the lecture. I read it, then I forgot about it. It would be useful if I can customize the time I can received them.

Two of our participants P2 and P5 who previously explained they never access photos online, trusted and relied on the notifications and made decisions based on them. For example, P5 explained that reminders have an impact on her grocery planning and shopping and became a daily *habit or routine* of checking phone notifications prior shopping or during shopping:

Reminders helped me a lot while planning and shopping. I am really sad I won't receive these reminders any more.

Statement	**Code**	**Quantity (number of participants)**
Never review and respond.	No	0
Review and respond until the second week.	Semi yes	1 (P2)
Review and respond until the third week.	Semi yes.	1 (P4)
Review and respond until the end of the study.	Yes	3 (P1, P3, and P5)

Table 6-4. Review and respond duration per participant

Table 6-4 explain how many participants reviewed and responded to push notifications during the study period. Three of our participants, P1, P3, and P5 kept reviewing and responding to pushing notifications until the end of the study. However, P2 kept reviewing until the second week due to the *contextual forces* such as her busy schedule and P4 until the third week of the study. P2 said:

I stopped reviewing the reminders around the second week because I didn't have time.

Recipe suggestion notifications based on available ingredients in the fridge did not motivate participants enough to try them. Moreover, notifications that remind participants to engage and to revisit the EyeFridge app was not motivation enough either.

In terms of notifications, they facilitated improved food waste outcome. Three participants, P1, P3, and P4, noticed reduction in their food waste and increased their attitudinal factors. P1 talked about how reminders and notifications had an impact on engagement for reduced food waste practices:

The notifications helped me to avoid buying items I already have in my fridge. I have noticed a little reduction in food waste.

Although some participants indicated they noted food waste reduction, it is difficult to claim that notifications and reminders have a direct impact on reducing food waste because it is difficult to measure the amount of food waste.

Theme	Data		
	Tracking	**Response**	**Interview**
Accessing photos online	Many clicks.	No many responses.	Varied from accessing to not accessing photos online.
Recipe recommendations	Not many clicks.	No many responses.	No engagement.
Receiving and reviewing notifications and reminders	All seen via whatsapp messages.	Not conclusive.	All engaged. Refer to Appendix J questions 2 - 5.

Table 6-5. Overview of themes with data collected

Continuing interaction with the notifications, though, suggests that maybe a very smart fridge that continually monitors its content and notifies owners when items run low would be useful. This highlights that notifications provide a positive incentive to interact. Notifications strengthen the *contextual force* represented by the fridge technology to motivate participants to use their enhanced *personal capabilities*, for example, information about fridge contents, and so to change their *routines and habits*.

6.5.5 Discussion

The context-aware system displayed real-time photos of fridge content and allowed users to access the images whenever they wanted. Displayed images raised the awareness of available food in the fridge and improved visibility of food items. This shows that forgetting available items inside the fridge is a major factor that currently leads to domestic food waste. However, findings indicated that consideration of future research has to be given to contextual use of EyeFridge. Participants had to remember to use EyeFridge and access photos online prior to or while shopping. This provided an opportunity for participants to display items available in the fridge and thus prevented them from buying unnecessary items that lead to food waste. However, this alone did not motivate users to change their behaviour and influence their

decision-making process.

Notifications open up a new form of interaction with persuasive context-aware technology to change behaviour through raising awareness, reflection, and promote consumer decision-making related to food management behaviour. Notifications increased consumers' awareness about their food supply knowledge and influence decision-making to take an action. The persuasive context-aware requires an initial effort to remember to use it thus notifications help users to anticipate interaction. Adding notifications to the persuasive context-aware technology increased the frequency of revisiting photos online from 1% in the first prototype study without notifications to 60% in the second prototype study with notifications included. These real-time events remind users to re-visit, re-engage with the EyeFridge, and re-access the photos. In terms of VBN theory, notifications encouraged users to create new a habit and routine of checking photos online. Nevertheless, the frequency of revisiting decreased to almost zero at the end of the second prototype study. Participants trusted the notifications completely and made decisions or actions upon receiving them. Raising awareness and reflection related to food management behaviour motivate participants to improve their decision-making.

Interviews indicated that many participants had stopped accessing photos after the third week of installing EyeFridge. Only one participant said they kept accessing photos. As shown in Figure 6-7, the majority of visits occur within the first two weeks, with a peak in the third and fourth week due to participants becoming familiar with the EyeFridge prototype. However, the activity level drops off on the final (fifth) week. The novelty effect faded over time and participants often forgot that EyeFridge is installed in the fridge. This can be explained in terms of the VBN theory *personal capabilities* variable. For example, P5 was motivated to use EyeFridge, but the excitement wore off. However, participants trusted the push notifications and to relate this to VBN theory it became a *habit or routine* to check notifications received then plan their next grocery shopping accordingly.

Users do not want pictures of the inside of the fridges; they want higher-level information that can be derived from those pictures (for example, what is still good, what has expired, what has run out, and what can I cook with what I have?). Users do not need to engage with

persuasive context-aware technology if they are already getting the information they actually care about from the notifications themselves. Nevertheless, the challenge to convert information to actions remains as the findings indicated that reminding users might be not enough because some participants explained in the findings that they did not make a decision after each notification received.

Notifications are an acceptable and appreciated method that change behaviour and support consumer decision-making process during food practices. Participants established new *habit or routine* of reviewing the notifications and make decision upon receiving them throughout the study period. Notifications updated users about different events, and users could take instant action or ignore the notification depending on the importance of it alongside the user's current context. Participants explained how the notifications helped them with planning and also during grocery shopping to remember items available in the household. Push notifications had an impact on long-term behaviour change by creating new *habits or routines* and influenced decision-making process related to food practices.

6.5.5.1 Design Requirements

Based on findings, a set of design requirements was proposed for future design of a persuasive context-aware system to encourage behaviour change in terms of creating new habits or routines and influence decision-making process.

- **Raising Awareness**

An extension of this work could be modifying the push notification system. In this study, the research acted as an agent and updated users manually using the Wizard of Oz approach. Future designers could design and build the infrastructure of effective notifications and reminders. One kind of technical challenge for designers is all the tasks that the Wizard of Oz carried out during the investigation; viewing fridge contents, identifying recipes, sending notifications. This may shed light on how to design an intelligent agent that enables the system to identify items in the fridge, recognize what items are running out, and push this information to the user. Updated notifications raise awareness of food knowledge thus encouraged users to change their behaviour in terms of *new habits or routines* and influenced

their decision-making process.

- **Non-interrupting:**

Another effective way to encourage behaviour change is that notifications should not disturb the current user's events. Future design should take advantage of status bar notifications. These notifications are non-interrupting. They do not ring or vibrate; they simply place an icon in the notification bar for a later action. They require enough force to promote an action, but they are not too bothersome (Tsai et al., 2007).

- **Customization:**

Users value customization and a personalised notification schedule. Some participants did not show a considerable behaviour change and said they could imagine being motivated to influence decision-making and behaviour change if they are in control of when and how they are alerted. Moreover, they should have the option to snooze their notifications if they cannot react straightaway. Also, users can customize receiving a notification based on location. For example, when the user pops into the shop, the user will get a location-based reminder about the items running out. This customization of receiving notifications might lead users to more immediate action. This level of customization represents a technical challenge that could be addressed by applying machine learning techniques to learn the user's habits or routines, and an agent that responded both to habits and to departures from usual habits.

- **Completion check:**

On some occasions, users may forget if they accomplished the task already (for example, if they bought that item running out). Therefore, users should be able to check whether a decision or action was undertaken in order to encourage behaviour change and influence decision-making. As long as the notification is visible on the lock screen or status bar, the users know they still have not undertaken any action.

6.6 Chapter Summary

The primary contribution of this chapter is an introduction and deployment of FridgeReminder that encourage long-term behaviour change through creating new *habits or routines* and influence decision-making process related to food practices. The nature of persuasive context-aware computing was extended to include pushing information to users. The Wizard of Oz approach raised awareness of food knowledge through initiating interaction with the technology or pushing information to users. However, users relied completely on receiving information (notifications) from the technology.

VBN theory helped explained how these notifications encouraged most participants to change their behaviour and influence decision-making process. Notifications strengthen the *contextual force* represented by the fridge technology to motivate participants to use their enhanced *personal capabilities*, for example, information about fridge contents, and so to change their *routines and habits*. Therefore, participants do not need to initiate interaction with the system as long as they get the information needed from notifications. Design requirements have been presented for a future design of persuasive context-aware technology for effective long-term behaviour change and influence decision-making process.

Chapter 7 Conclusions

The goal of this thesis has been to design, develop, and investigate the impact of persuasive context-aware technology on behaviour change in the long-term and influence decision-making process. This thesis investigated how contextual data collected from a context-aware system could support the consumer's memory by turning the contextual data into visual data that could be accessed through a novel web user interface or by pushing information automatically to the user. A total of three studies were undertaken to answer research questions RQ1 and RQ2.

The research narrative in this thesis cover strategy was adopted to answer research questions. It includes interviews, first prototype and second prototype. The findings was structured and analysed in terms of VBN variables. The discovery that availability of information about fridge contents was not sufficient to overcome existing habits and routines and other contextual factors, which led to the introduction of notifications and reminders and the eventual conclusions that were drawn. The sample sizes in the studies here were small and fitted well with that recommendation by Nielsen and Molich (1990). They argued that large samples of design evaluators could reduce the quality of outcomes and recommended a small group of about three to five design evaluators.

This chapter concludes the body of work that has comprised this thesis by describing how the research questions were answered. The limitations of this thesis are reflected upon, and the contributions of this thesis to knowledge are stated. Finally, recommendations for future work are outlined.

7.1 Answering the Research Questions

This section answers the research questions introduced in Chapter 1 that guided the research presented in this thesis. Each of these research questions was investigated through sub-questions, which together addressed the main aspects of the research questions. In this section, the research questions are presented together with their sub-questions. Each of these sub-questions is answered, and references are given to the chapters addressing the questions in more detail.

7.1.1 RQ1: Why do consumers waste food?

Chapter 4 explored the first research study in this thesis, which examined the key factors influencing consumer decision-making leading to food waste. Individual interviews with seven participants along with in-home tours were conducted. The findings of this study indicated that two major factors and three minor factors are associated with consumer decision-making leading to food waste.

7.1.1.1 Which factors influence consumer decision-making leading to food waste?

A review of behavioural psychology literature uncovered a large variety of behaviour models and factors (section 2.2 and section 4.1). A combination of attitudinal factors, *contextual forces, personal capabilities*, and *habits* made the value-belief-norm (VBN) theory (Stern, 2000) a suitable framework to identify the relevant factors and how they relate to each other. Participants in this study were interviewed with in-home tours. The findings indicated that consumer decision-making behaviour leading to food waste could be affected by two major factors and three minor factors. The major factors are:

- **Remembering available food:** Do consumers retrieve available items in their storage spaces?
- **Remembering location of available food:** Do consumers remember location of available items in their storage spaces?

Three further minor factors were identified that influence consumer decision-making activities leading to food waste:

- **Measuring correctly:** Do consumers measure the correct portion they intend to consume?
- **Unconsumed ingredients and leftovers:** Do consumers have the intention to consume unwanted ingredients and leftovers?
- **Changing circumstances:** Do consumers face contextual forces that lead to unconsumed food purchase?

7.1.1.2 Which factor has the major effect on consumer decision-making resulting in food waste, and how can this factor support the design of a context-aware system?

During the first study in Chapter 4, all participants indicated that forgetting available food in the household has the major impact on their behaviour leading to food waste. The intervention proposed in this thesis (Chapters 5 and 6) focused on this major factor by supporting consumer food practices during planning or during food shopping.

7.1.2 RQ2: How could persuasive technology help consumers change their behaviour so as to waste less food?

The remaining two studies, the first prototype and second prototype (Chapters 5 and 6) inform the design of a future intervention system and could play a key role in reducing food waste. Moreover, design limitations that detract from real-users studies were highlighted as well as ways to improve the future design.

7.1.2.1 What impact does easily accessible information about available food in the house have on behaviour change and decision-making process?

In Chapter 5, the first prototype design was presented. A capturing device (Samsung phone) was used to sense and collect data from the home environment (storage space). The smart phone captured two types of data: motions and photos. The mobile phone has a built-in

accelerometer that senses the movement and a built-in camera that turns the raw data collected from sensing movement into meaningful visual data. Also, date and time of captured photos were printed on each photo captured. Users can access these photos though a novel web user interface.

During the first prototype investigation in Chapter 5, participants in the first prototype study who were introduced to the basic context-aware persuasive technology did not need such a technology to influence their decision-making process, and, surprisingly, did not change their behaviour. Enabling VBN theory, the technology did not encourage participants to establish new *habits or routines* of examining the fridge content online due to *contextual forces* and *personal capabilities* such as busy lifestyle, fridge size and having a good memory. This prototype required an effort from users to initiate interaction to support their decision-making.

7.1.2.2 What impact does notifications and reminders have on behaviour change and decision-making process?

In the second prototype 'EyeFridge' study in Chapter 6, the photos collected from the passive context-aware system in combination with pushing information over to the user, helped users to retrieve information about food available and raised their awareness of food storage. Users accessed these photos though a web user interface that helped inform decision-making when planning or during food shopping. Although photos were the most supportive data, participants stopped viewing photos and relied on information received. To explore how a passive context-aware system would be perceived, used, and experienced, the EyeFridge evolved into a five-week field study with five participants. Findings indicated that participants enjoyed accessing photos online, and they also appreciated receiving notifications and reminders to their phone. However, displaying photos online did not provide enough engagement over the long term. In contrast, engagement was maintained throughout the study by receiving, reading, and making an action based on the information received through notifications and reminders.

The second prototype of context-aware persuasive technology encourages long-term behaviour change through and influence decision-making process related to food practices. VBN theory helped explain how these notifications encouraged most participants to change their behaviour and influence decision-making process. This is due to *habits or routines* variable of VBN theory, the notifications encouraged participants to create these new *habits/routines* by reading these notifications received and then plan their next grocery trip. The nature of persuasive context-aware computing was extended to include pushing information to users. The Wizard of Oz approach raised awareness of food knowledge through initiating interaction with the technology or pushing information to users. The study in Chapter 6 shows that notifications and reminders supported long-term engagement to retrieve information about available food in the household. Participants engaged and accessed photos online to a certain point of the study. After that, they relied completely on notifications to get information needed. Once the notifications were added to the system, engagement increased from 1% without notifications (first prototype) to almost 60% with notifications (second prototype). This result was confirmed in the EyeFridge study in Chapter 6 when the notifications were integrated in the system. Participants kept reading and responding to notifications until the end of the study.

7.1.2.3 How can we determine whether such a technology reduced food waste?

Although three out of the five participants in the final study (Chapter 6) noted food waste reduction upon using the passive context-aware system, it is difficult to claim that using such a system will promote a sustainable lifestyle. This is due to the small sample size of the study and the difficulty in measuring food waste during the study. Nielsen and Molich (1990) argued that large samples of design evaluators could reduce the quality of outcomes and recommended a small group of about three to five design evaluators.

7.1.2.4 How can we improve the future design of the passive context-aware system?

Design requirements have been presented for a future design of persuasive context-aware technology for effective long-term behaviour change and influence decision-making process. The passive context-aware persuasive technology system should:

- Raise awareness: Notifications raise awareness of food knowledge thus encouraged users to change their behaviour in terms of new habits or routines and influenced their decision-making process.
- Non-interrupting: Notifications and reminders should not get in the way of the current user's activities.
- Customization: Users should be able to control how and when they are notified.
- Completion check: Users should be able to check whether a decision or action has been taken.

Research Question	**Methods**		**Data Analysis**	**Main Contribution**
Why do consumers waste food?	Interviews In- home tour		Thematic analysis Visual ethnographic techniques	• Key factors influencing consumer decision-making leading to food waste. • Two major factors and three minor factors. • Remembering available food in storage spaces has the major impact on food waste and could be supported in designing future interventions.
How could persuasive technology help consumers change their behaviour so as to waste less food?	First prototype of persuasive context-aware technology	Focus group Visual ethnographic Web traffic	Thematic analysis Visual ethnographic techniques Web analysis	• First prototype of context-aware persuasive technology has a negative impact on encouraging behaviour change and influence decision-making.
	EyeFridge - Second prototype An improved version of first prototype	Interviews Visual ethnographic Web traffic Review and response to notifications	Thematic analysis Visual ethnographic techniques Web analysis See function on whatsapp and reply with word 'OK' if an action is made.	• Notifications and reminders integrated in context-aware persuasive technology encourage long-term behaviour change through creating new *habits or routines* and influence decision-making process related to food practices. • Notifications and reminders encourage users to initiate interaction and engagement with the system over the long term. Engagement increased from 1% in first prototype without notifications to almost 60% with notifications. • Design requirements of persuasive context-aware technology for effective long-term behaviour change and influence decision-making process.

Table 7-1. Answering research questions proposed in this thesis

7.2 Contributions to Knowledge

During the project described in this thesis, a variety of research studies have been conducted, and hence created the basis for the development of two persuasive context-aware designs. In addition to the development of the systems, the project has resulted in a few contributions to knowledge. Some are direct consequences of answering the research questions, and some resulted from the research without being directly related to the research questions. The contributions to knowledge resulting from this PhD project are the following:

7.2.1 Factors influence decision-making leading to food waste

Several studies have identified causes that influence consumer purchase behaviour (Green & Vergragt, 2002; Spangenberg & Lorek, 2002; Carrigan & Attala, 2011). However, there was a gap on which factors influence consumer decision-making resulting in food waste. The findings in this thesis identified two major factors: remembering available and location of food. Also identified three major factors, which are measuring correctly, unconsumed ingredient and changing circumstances.

7.2.2 The impact of context-aware persuasive technology on behaviour change

Context-aware persuasive technology did not change consumer's behaviour so as influence decision-making process related to food practices. Due to the *contextual forces* and *personal capabilities* identified, the technology did not encourage changing participants' *habits or routines*. This raised an opportunity to modify the technology so as to encourage participants to change their behaviour. The first prototype required users to initiate interaction to change their behaviour and influence their decision-making process. The fact that *contextual forces* and *personal capabilities* outweighed the incentive to initiate interaction with the information indicates the need for an improved version of this prototype. The second prototype incorporate features such as pushing information over to users instead of requiring them to initiate interaction with the technology.

7.2.3 The impact of notifications on behaviour change

Notifications encouraged long-term behaviour change by creating new *habits or routines* related to food practices and so as effect decision-making process. Notifications strengthen the *contextual force* represented by the fridge technology to motivate participants to use their enhanced *personal capabilities*, for example, information about fridge contents, and so to change their *routines and habits*. This shows that users do not need to engage with the context-aware system if they already are getting the information they actually care about from the notifications themselves. Nevertheless, the challenge to convert information to actions remains as the findings indicated that reminding users might not be enough.

7.3 Limitations and Future Work

There are always limitations associated with every research undertaken. It is important to identify the limitations that could influence the contributions of this thesis. These limitations provide context to the research that interpretation and impact the validity of this thesis. Many opportunities arise that can be considered for future study based upon the research results described in the previous sections. In this section, limitations and opportunities are outlined for future work.

- Household type and culture

The investigations presented here focused on young professionals in shared accommodation. Future work should focus on conducting investigations on populations outside of the shared houses and into different households and contexts such as older adults, single-family detached household, and multi-family household. According to WRAP (2010), the amount of food and drink waste produced from each member in the household decreases with increasing household size, and the most is generated from young adults and people over 65 years old. These kinds of inquiries are important prerequisites before carrying a field deployment of a passive context-aware system. It is vital that researchers and designers familiarize themselves with social and environmental contexts of use before deployment.

Another recommended future work is to compare and contrast a context-aware system design and investigation in different cultures and regions around the world. The potential claim is that a passive context-aware system that focuses on a larger population could be a more effective motivator of ecologically sustainable behaviour for Eastern people than Western. Bond and Hwang (1986) argue that Westerners are more individually oriented, whereas Easterners are more socially oriented. This can be achieved through ethnographic or survey-based inquiries, and through small and short deployments as with the approach taken in Chapters 5 and 6. The other approach is familiarization with existing relevant literature.

- Participant's bias

Another limitation here is the bias of our participants' base. Most of our participants were biased toward sustainable attitudes and beliefs. This limits the findings and implications of this thesis to a slimmer population. In future work, it is important to extend to other types of study population such as those not interested in sustainability, or those having negative attitudes about sustainable lifestyles. This might influence the passive context-aware design. There should be a way to engage these populations in sustainability issues and leverage this knowledge in passive context-aware design.

- Push information

Notifications and reminders received to the user's phone must be read, and sometimes a decision is required upon receiving them. Some participants forgot to read the message, or sometimes they read it and decided to make a decision later and then forgot about it.

- Industrial collaboration

Another limitation is that this thesis lacks industrial collaboration. The collaboration of such a partner would have contributed much-needed funds, expertise, prototyping skills, and access to a wide range of consumers for research purposes. This was considered to be acceptable for the conceptual design outcome within the scope of this thesis. To strengthen the practical significance of the design, more partners from industry should be involved in the design process to solve the design issues.

7.4 Chapter Summary

This chapter concludes the thesis by presenting the major findings from the research studies conducted in the thesis that inform and investigate the research questions. The main contributions are outlined along with answers to research questions proposed in Chapter 1. Thesis limitations are also presented with directions for future research. These are related to the sample size, length of the study, push information, industrial collaboration, and participant's bias. However, despite these limitations, the work has resulted in some useful contributions.

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Appendix A Study 1 Recruiting Email

Hello,

My name is Bushra Alolayan, and I'm running a study for my PhD project that focuses on promoting sustainable lifestyles. In order to collect qualitative data, I'm looking for people who may be interested in participating in an interview session that focuses on identifying factors influencing consumer decision-making leading to domestic food waste.

You will be asked several questions related to food storage practices, planning and grocery shopping behaviour, cooking and food waste management. After conducting interviews, the researcher will ask your permission to do an in-home tour and show the researcher current food waste in the household, and where and how you store food. The researcher will also take pictures during the tour.

We will meet for one session that will last for approximately one hour.

The study will be held at your house at a mutually agreed time.

If you are interested please reply to this email with your contact information or call me at 07946091765. I will contact you back to ask you some questions to decide if you qualify for the study.

If you have any questions, please contact me at bua3@aber.ac.uk

Thank you for your interest,

Bushra Alolayan

PhD student

Aberystwyth University

Appendix B Study 1 Consent Form

Introduction

This research study is aim to promote a sustainable lifestyle using technological interventions.

Procedures

You will be asked to answer individual interview questions to explore attitudes and behaviours relating to planning, grocery shopping, cooking, food storage practices, and food waste management. The interview involves of 29 questions and will take approximately 45 minutes, which will involve audio recording of your interview with the researcher.

Risks/Discomforts

There is no risk anticipated for you while taking part in this study.

Confidentiality

The data collected, including interviews' answers and audio recordings, will not be used for any other purpose than the study and participants will not be named. The researcher will ask your permission to use pictures at public presentations and conferences and will do so if you give written permission for that. The data collected will be kept strictly confidential and only used by the research team.

The researcher has the rights to disclose the aims and background of the project, as well as publish and disseminate results in a conference paper.

Participation

Participation in this research study is voluntary. You have the right to withdraw at any time without explanation.

If you have questions regarding this study, please contact Bushra Alolayan at 01970628470, bua3@aber.ac.uk or Dr Edel Sherratt at 01970622448, eds@aber.ac.uk

Participant:

_____	_____	_____
Name of Participant	Signature	Date

Researcher:

__Bushra Alolayan_____	_____	_____
Name of Researcher	Signature	Date

Appendix C Study 1 Interview questions

Domestic food storage practices:

1. How do you store food in the cupboard and fridge? Do you follow a systematic approach?
2. Do you face problems with low visibility of food items within the fridge?
3. Do you think the way you store food has an impact on food waste?
4. Do you think limited fridge space has an impact on food waste?

Food shopping and purchasing practices:

1. Do you always have knowledge of available food in your household?
2. Does this lead to purchasing items you already own?
3. Do you plan your grocery shopping? Do you make a list?
4. Do you do your shopping according to planned meals?
5. Do you examine the fridge/cupboard/pantry before creating a shopping list?
6. How often do you do grocery shopping?
7. Do you shop from a major supermarket chain/deli/farmer market?
8. Why do you shop at this particular supermarket?
9. Do you purchase in bulk?
10. Do you think buying bulk saves you money?
11. Do you think buying bulk increases food waste?
12. Do you buy fresh food on special offers?
13. Do you buy products that are reduced because they are damaged / near their sell by date?
14. Do you check several packets of the same product to find the one with the longest expiry date?
15. Do you remember items' locations in fridge/cupboard?

Food cooking and consumption practices:

1. How often do you cook?
2. Do you cook large or small meals?
3. Do you consume the leftovers?
4. Do you always recall you have leftovers?
5. Did you have negative experiences with a particular food previously?
6. Are you creative with cooking? For example, use food before they expired?
7. Have you experienced unexpected events that led to a cancelation of planned meals?

Food waste management practices:

1. How do you handle expired food?
2. What quantity of food waste do you produce?
3. Do you give left over/ unwanted food to pets?

Appendix D Study 2 & 3 Recruiting Email

Hello,

My name is Bushra Alolayan, and I'm running a study for my PhD project that focuses on promoting sustainable lifestyles. In order to collect qualitative data, I'm looking for people who may be interested in trying out a new intervention related to reducing food waste and giving feedback after using it.

What will I be doing in this study?

The researcher will install a mobile phone inside your fridge to take pictures of the fridge content every time the fridge door is open. The pictures will be uploaded to a dedicated website where you can access the photos taken. The phone will be kept inside your fridge for a five-week period, and you are asked to use it as you desire.

At the end of the study, you will be asked questions about your thoughts and insights of the intervention.

How long is a session?

We will meet for two sessions: one at the beginning of the study and one when the study is complete. Each session will last for one hour. The whole study will last for five weeks.

When and where?

The study will be held at your house at a mutually agreed time.

If you are interested please reply to this email with your contact information or call me at 07946091765. I will contact you back to ask you some questions to decide if you qualify for the study.

If you have any questions, please contact me at bua3@aber.ac.uk

Thank you for your interest,

Bushra Alolayan

PhD student

Aberystwyth University

Appendix E Study 2 & 3 Recruitment Questions

1. How old are you?
2. How many people live in this property?
3. What type of dwelling do you live in?
4. Do you make compost?
5. Do you use a computer?
6. Do you own a smart phone? Can you use it to connect to a website?
7. Is there a spare power plug near your fridge?
8. Do you have a Wi-Fi access in your house?
9. Are you happy for me to contact you about three times while the experiment takes place?
10. What is your preferred contacting method?

Appendix F Study 2 & 3 Consent Form

Introduction

This research study is aim to promote a sustainable lifestyle using technological interventions.

Procedures

You will be asked to take part in a fieldwork experiment that consists of installing a mobile phone inside your fridge for a period of five weeks, followed by an individual interview. The interview consists of between 2 and 16 questions and will take approximately 45 minutes. Questions will include details about the project, and whether or not the phone inside the fridge helped reduce food waste and change your behaviour during the study period.

This study involves capturing images of your fridge content and the audio recording of your interview with the researcher.

Risks/Discomforts

There is no risk anticipated for you while taking part in this study.

Confidentiality

The data collected, including interviews' answers and audio recordings, will not be used for any other purpose than the study and participants will not be named. The researcher will ask your permission to use pictures at public presentations and conferences and will do so if you give written permission for that. The data collected will be kept strictly confidential and only used by the research team.

The researcher has the rights to disclose the aims and background of the project, as well as publish and disseminate results in a conference paper.

Participation

Participation in this research study is voluntary. You have the right to withdraw at any time without explaination.

If you have questions regarding this study, please contact Bushra Alolayan at 01970628470, bua3@aber.ac.uk or Dr. Edel Sherratt at 01970622448, eds@aber.ac.uk

Participant:

_____	_____	_____
Name of Participant	Signature	Date

Researcher:

__Bushra Alolayan_____	_____	_____
Name of Researcher	Signature	Date

Appendix G Study 2 Instruction

Welcome and Purpose

First of all I would like to thank you for participating in this study. Please find below some information about what you will be doing during the study. If you have any questions please ask before we get started.

I am asking your permission to install a mobile phone inside your fridge. Every time you open the fridge door, the phone will sense the movement and take a picture of your fridge contents, and then upload it to a dedicated website where you can view the images via your computer or mobile phone. Our goal is to see if this intervention has an effect on reducing food waste and increasing the awareness of available food.

Researcher's Role

During the first session, I will install a mobile phone inside your fridge for a five-week period.

During the second session, I will ask you between 2 and 12 questions on your thoughts about the fridge, and whether or not you would like to keep the phone inside the fridge.

Test Participant's Role

The website displays the latest eight photos of the fridge contents. You can log in using the following details to check the contents of your fridge:

Website:	www.eyefridge.uk
Username:	User1
Password:	Qaz1wsx2

The second sessions will be voice recorded for reference.

In case of emergency, please contact me on:

- Email: bua3@aber.ac.uk
- Phone: 07946091765

Appendix H Study 2 Focus Group Questions

1. What is you first thought and experience with the eyeFridge?
2. Did you use the prototype/log in to the app?

<u>If yes:</u>

3. Does the eyeFridge raise your awareness of available food in your fridge?
4. Did it help you in planning your grocery shopping?
5. Do you think such a technology will help reduce your food waste?
6. How difficult did you find your participation?
7. Did you face any difficulties using the eyeFridge or the web application?
8. Why did you log in to the app?
9. How did you access the images? Through a mobile, tablet, laptop or PC?
10. Did you access the images while you were at the shop?
11. Did you talk about the project or recommend it to friends?
12. Can you see yourself using it for a longer period?

<u>If no:</u>

13. What are reasons preventing you from using the prototype/log in to the app?
14. What changes should be done to encourage participation with the prototype/log in to the app?

Appendix I Study 3 Instruction

Welcome and Purpose

First of all I would like to thank you for participating in this study. Please find below some information about what you will be doing during the study. If you have any questions please ask before we get started.

I am asking your permission to install a mobile phone inside your fridge. Every time you open the fridge door, the phone will sense the movement and take a picture of your fridge contents, and then upload it to a dedicated website where you can view the images via your computer or mobile phone. Our goal is to see if this intervention has an effect on reducing food waste and increasing the awareness of available food.

Researcher's Role

During the first session, I will install a mobile phone inside your fridge for a five-week period.

At the end of this study, I will ask you between 2 and 16 questions on your thoughts about the fridge, and whether or not you would like to keep the phone inside the fridge.

Test Participant's Role

You can log in using the following details to check the contents of your fridge:

Website:	www.eyefridge.uk
Username:	user2*
Password:	wsx1edc2*

* Each participant has a different username and password.

The website has three main features: FridgeGallery, FridgeRecipe and FridgeReminder.

FridgeGallery: Displays the latest images of the fridge content.

FridgeRecipe: Suggests recipes based on the fridge content.

FridgeReminder: Receive reminders and notifications on user's phone when items missing out, recipe suggestions, and reminder to reuse the app.

The second sessions will be voice recorded for reference.

In case of emergency, please contact me on:

- Email: bua3@aber.ac.uk
- Phone: 07946091765

Appendix J Study 3 Individuals Interview Questions

1. What is you first thought and experience with the eyeFridge?
2. What do you think of the reminders and notifications?
3. Did it help you with planning and shopping?
4. Did you keep reviewing the notifications received?
5. Did you make an action after receiving them? For example, you received a reminder about an item missing; did you pop into the shop afterwards to buy it?
6. Did you use the prototype/log in to the app?

<u>If yes:</u>

7. Did the eyeFridge raise your awareness of available food in your fridge?
8. Did it help you while planning your grocery shopping?
9. Do you think such a technology would help reduce your food waste?
10. Did you face any difficulties using the eyeFridge or the web application?
11. Why did you log in to the app?
12. How did you access the images? Through a mobile, tablet, laptop or PC?
13. Did you access the images while you were at the shop?
14. What do you think of the recipe suggestion feature? Did you try any of the recipes?
15. Did you talk about the project or recommend it to friends?
16. Can you see yourself using it for a longer period?

<u>If no:</u>

17. What are reasons preventing you from using the prototype/log in to the app?
18. What changes should be done to encourage participation with the prototype/log in to the app?
19. Did you talk about the project or recommend it to friend?